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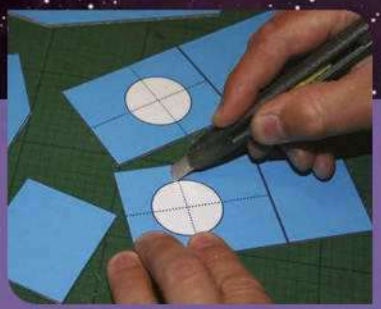
THE BIG BOOK OF DIY ASTRONOMY PROJECTS

Make your own equipment using everyday objects



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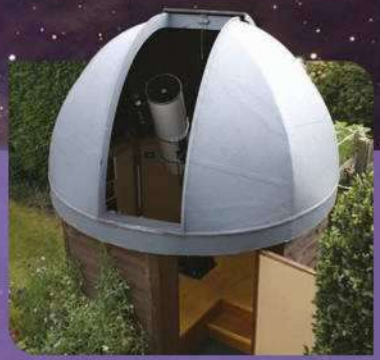
STEP-BY-STEP instructions for all 33 builds



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WELCOME

Amateur astronomers have a proud tradition of making their own equipment. This do-it-yourself ethos was evident from the very beginning: the telescope that Galileo used to make his revolutionary observations of Jupiter's largest moons was a product of his own hands. Closer to our own time, many innovations we see on commercial telescopes today appeared first on home-built instruments: the Dobsonian telescope, its simple design invented by US amateur astronomer John Dobson, and the Crayford focuser, first designed in the 1960s by UK amateur John Wall.

The *Big Book of DIY Astronomy Projects* follows this heritage and on the following 114 pages you'll find all the information and instructions you need to cost-effectively build, equip and upgrade your home viewing platform. We'll show you how to do everything from making a simple device to measure the distances between stars to building your own telescopes, a 360° camera and – if you're feeling particularly ambitious – a domed observatory for your garden.

Each project has a full outline of the item under construction and its purpose, the tools and materials needed to build it, plus step-by-step instructions to put it all together. Before you make anything though, check the online bonus content section at www.skyatnightmagazine.com, where you'll find loads of free, extra resources including plans, pictures, cutting templates and diagrams.

"You'll find all the information you need to build, equip and upgrade your home viewing platform"

So pick up your tools and join our expert astronomers and craftsmen on the following pages to take your equipment and observing to the next level!

Chris Bramley
Editor

EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editors Rob Banino, Jane Williamson

CONTRIBUTORS
Ben Kent, Simon Lang, Pete Lawrence, Robert Lucas, Mark Parrish, Terry Pearce, Steve Richards Vince Sellars, Stephen Tonkin, David Utting

CIRCULATION / ADVERTISING
Head of Circulation Rob Brock
Advertising Managers
Neil Lloyd (0117 300 8276)
Tony Robinson (0117 314 8811)

PRODUCTION
Production Director Sarah Powell
Production Coordinator Derrick Andrews
Reprographics Tony Hunt, Chris Sutch

PUBLISHING
Publisher Jemima Dixon
Managing Director Andy Marshall
CEO Tom Bureau

BBC WORLDWIDE
Director of Editorial Governance Nicholas Brett
Director of Consumer Products and Publishing Andrew Moultrie
Head of UK Publishing Chris Kerwin
Publisher Mandy Thwaites
UK Publishing Coordinator Eva Abramik
uk.publishing@bbc.com

www.bbcworldwide.com/uk--anz/ukpublishing.aspx

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THE WRITERS

Ben Kent

Ben is an amateur astronomer who observes the night skies from his home in Aberdeenshire

Simon Lang

Simon is the chairman of the Camden Astronomy and Telescope Making Society

Pete Lawrence

Pete writes *BBC Sky at Night Magazine*'s Sky Guide section and is an award-winning astrophotographer

Robert Lucas

Robert wrote the original software for the PIRATE telescope system. See his work at www.virtual-science.co.uk

Mark Parrish

Mark makes furniture for a living and has been building astronomical equipment for 20 years

Terry Pearce

Terry is an amateur astronomer and has been teaching people to make their own telescopes since 1967

Steve Richards

Steve is *BBC Sky at Night Magazine*'s Scope Doctor and the author of *Making Every Photon Count*

Vince Sellars

Vince is a retired healthcare worker with a keen interest in astronomy and has been exposing solargraphs for years

Stephen Tonkin

Stephen has been making astronomy kit since his student days, in the 1970s, when he started grinding his own optics

David Utting

David is a doctor now but has been an amateur astronomer ever since reading Patrick Moore's *The Universe for the Under Tens*

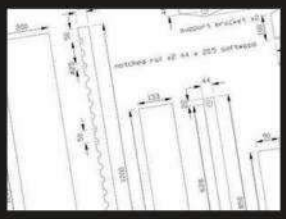
BACKGROUND IMAGE: ISTOCK

More online

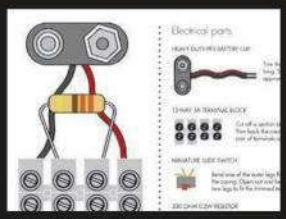
You'll find extra resources on our website to help you make many of the projects in this issue.

How to find it

Visit www.skytnightmagazine.com/bonuscontent, select the DIY Astronomy section from the list and enter the authorisation code W5TKHFR when prompted.



Parts drawings
Print out full parts lists complete with measurements for many of the projects.



Wiring diagrams
Find helpful schematics showing you how to put together electrical circuits.

Extra photos
Consult extra images to help guide you through key moments in construction.

Calculations
Use handy spreadsheets to easily work out the correct dimensions for builds.

MORE ONLINE

Where you see a project with this box on the following pages, you'll find more resources on our website to go with it.

Yours doesn't need to be as comprehensive as the author's (Mark builds furniture for a living), but our guide will get you on the way to having your own DIY den

A DIY astronomer's WORKSHOP

Get yourself tooled up and organised to tackle our astronomy builds

By Mark Parrish

To make the projects described in this special issue, you'll need some tools and a suitable workspace, so here we'll advise you about the equipment you need to get started.

Choosing the right toolkit should not involve spending lots of money or sourcing extravagant machinery. You may have many of the items on our list already, but if not, everything can be bought from your local DIY store. The tools are also useful for jobs around the home, so you will find plenty of applications for them between projects.

A fully equipped workshop would be a dream scenario, and professionals and DIY aficionados may wish to add to our basic list, but the aim here is to give some sensible suggestions to those of you who are just beginning.

Tools

We recommend purchasing good quality tools, although this does not necessarily mean the most expensive or flashy looking. Select well-known brands and seek advice by reading reviews; good tools won't let you down and will last a lifetime. Secondhand examples can be found for attractive prices, but if they have been mistreated they may be ineffective or dangerous, so proceed with caution.

Most of these tools are hand operated, but three power tool alternatives are recommended for saving time and reducing some of the effort involved. A cordless drill with a selection of bits will make short work of drilling in wood, metal and plastic. It can also be used to drive screws. Buy a small one, which you can hold with one hand rather than a monster machine designed for drilling through masonry. A jigsaw is great for cutting curves in sheet materials, but by clamping a straight edge to your work it can accurately follow a line too. Lastly, a power sander takes the hard work out of smoothing and preparing for a finish.

Workspace

A dedicated workspace means you can leave your projects out between sessions and allow paint or glue to dry overnight. A garage or dry shed space is ideal, or perhaps a spare room, but be careful that small children can't access unattended sharp tools.

A purpose-built workbench is great, but a sturdy old table would serve as a good alternative. This could be stiffened up with extra wood if necessary and fitted with a rack for materials below. Trestle tables with a thick board on top could provide a useful, temporary setup or, if space is really tight, you could consider making a protective cover for your kitchen worktop or table from 12mm MDF.

A vice, screwed or clamped to the bench, is perfect for holding work while you cut and shape it, and good lighting aids accuracy and safety, so consider adding a desk lamp to supplement your room's lighting. Lastly, storing your tools in a sturdy box, bag or in racks will help to keep them in good condition, and they will also be easier to find when you need them. Store all of your small parts nearby in labelled trays, boxes or pots.

Work safely

Any practical work is potentially dangerous, especially when it involves sharp tools, but with care and precautions you will stay safe.

When you are sawing or drilling, ensure that the material is held securely with a vice or clamps – not with your other hand. Always cut away from your fingers

ALL PICTURES: MARK PARRISH

when using a knife. With safety in mind, think about what will happen when you complete a cut or drill through a piece of work before you begin.

Wear safety glasses or goggles if you are using power tools or a hammer, and guard your ears with defenders or plugs. Dust can be hazardous so be sure to wear a mask when sanding, and keep your workspace clean with a vacuum cleaner.

A useful tip is to wear disposable gloves when you're painting or varnishing to protect your skin. Lastly, it's a good idea to wear an apron or overalls – it not only keeps your clothes clean and offers additional protection, it also instills a sense of care and attention to detail in the work you are producing.

A DIY astronomer's toolkit

Equipment and tools: 37 essential items for your workshop

Workspace
1 Bench
2 Bench vice (or use clamps)
3 Adjustable lamp
4 Tool storage (box, bag or rack)
5 Small parts storage (tray, boxes or pots)

Marking out
6 Pencil and permanent marker
7 Steel rule (also use with craft knife)
8 Tape measure
9 Adjustable square (measures/marks depths)
10 Centre punch (mark holes prior to drilling)

Cutting and shaping
11 Craft knife (and spare blades)
12 Cutting mat (keeps knife tip sharp)
13 Hand drill (or upgrade to cordless drill)
14 Drill bits (HSS bits cut most materials)
15 Handsaw (not for metal)
16 Coping saw (not for metal)
17 Hacksaw (any material, full or junior size)
18 Files (half round and round)
19 Plane

Smoothing and finishing
20 Sand paper (coarse, medium and fine)
21 Sanding block
22 Paint brushes (also use for glue)

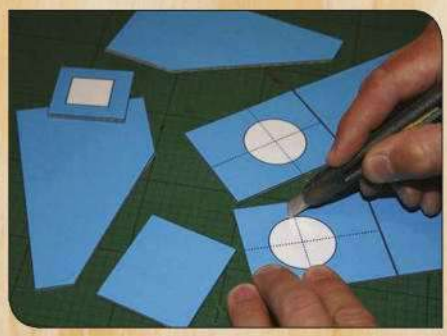
Assembly
23 Screwdrivers (set or holder with bits)
24 Spanners (set or adjustable)
25 Hammer (manageable size)
26 Allen keys
27 Thin pliers/cutters
28 Clamps

Powering up
29 Cordless drill
30 Jigsaw
31 Sander

Safety
32 Safety glasses/goggles
33 Disposable gloves
34 Ear defenders
35 Dust mask
36 Brush
37 Apron

ACCESSORIES

Stands, seats, shields and spectroscopes... with a few easy-to-source materials and a bit of know-how you can build all the things you need to complement your optical equipment and improve your observing sessions



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Make a **binocular** dew shield

By Stephen Tonkin

Keep dew off your binoculars with this low-tech accessory

If you mount your astronomical binoculars, they spend a long time aimed at the sky, resulting in much more radiative cooling than you get with handheld use. With few exceptions, binoculars don't have any form of dew shield and the consequence is that you can find your observing session cut short by the fading mushy images that are the sign of dew forming on your objective lenses. So here we show you how to make a simple dew shield to extend your observing sessions.

Dew forms when an object cools to a temperature called the dew point. The actual temperature of this threshold depends upon the humidity of the air. As the air cools, it can't hold so much moisture, so the relative humidity increases until it reaches 100 per cent, the point when moisture condenses out of the air.

ALL PICTURES: STEPHEN TONKIN

▲ Using a firm foam exercise mat will prevent the dew shields from sagging with age

If your objective lenses are radiating heat into a clear sky more rapidly than the sky is radiating it back, the glass they're made from will lose heat. The glass can cool more rapidly than the surrounding air, in which case the moisture will condense on the surface in the form of dew. Passive dew shields work by limiting the area of sky that your objective lenses can 'see' at any one time, thereby reducing the rate at which they can cool.

In order to be properly effective, the length of a shield needs to be at least three times the diameter of the aperture. But very few commercially available dew shields are sufficiently long, which is one reason why many telescope users resort to dew heaters. When dew shields are long enough, they can be unwieldy with large apertures and can also catch the wind. But with 70mm binoculars, for example, we'd suggest making the shields 250mm

STEP-BY-STEP

Step 1

Cut a strip of exercise mat about 15mm wide. Stick a bit of the Velcro tape to one end and wrap the strip around the aperture of one of your objective lenses. Mark where the Velcro tape overlaps and cut the strip to this length to form a template.

Step 2

Use your template strip to mark the required width of mat and cut two rectangles off the roll. For the length, decide how far you want your dew shield to project, then add 40mm to allow for sufficient to adequately sleeve your binoculars' apertures.

Step 3

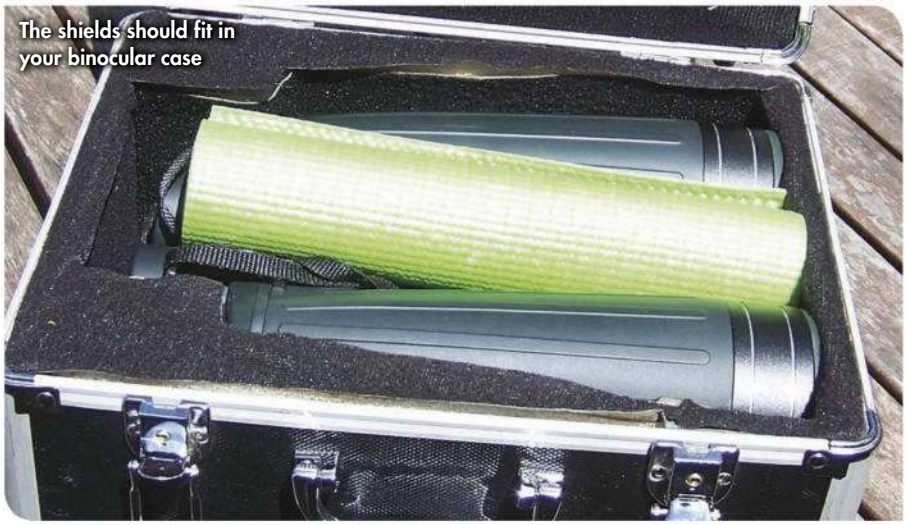
Gently press strips of Velcro tape to the sides of the dew shield and wrap it around the binoculars' apertures to make sure the pieces fit properly. If you do not press the tape on too firmly, you should be able to reposition it if necessary.

TOOLS AND MATERIALS

Materials
A firm foam exercise mat 2–3mm thick of any colour, 60cm of self-adhesive Velcro tape.

Sundries
A small amount of vegetable oil for greasing, polyester sewing thread, a steel rule.

Tools
A scalpel or utility knife with a fresh blade, a cutting mat, a sewing machine with a size 100/16 or thicker needle and a regular point (or equivalent hand needle, if you prefer to sew without a machine).


The shields should fit in your binocular case

long, of which 40mm will wrap around the binoculars' objective barrels.

If they're this size, the shields will probably fit in your binocular case when they're rolled up, reducing your chances of leaving them behind when you go out observing. If they're any longer than this, they may start to impede the light path.

A good material for making shields is the foam used for exercise mats. We found that the cheaper ones tend to be less flexible and so are preferable for making shields – too flexible and the shields may sag. For many, black is the preferred colour because it reduces internal reflectivity, but if the shield is long enough, you won't be able to detect any difference in reflections between the colours. That said, lighter colours are easier to see in the dark, so may be preferable if the shield is dropped.

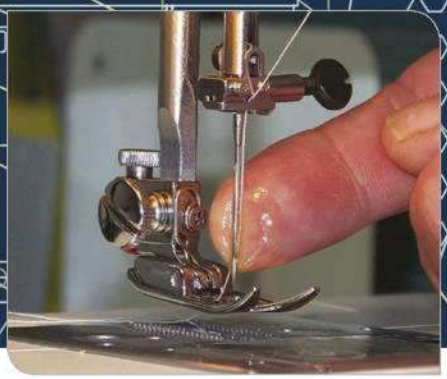
Build considerations

Self-adhesive Velcro tape is easier to work with than the non-adhesive alternative, but it has a couple of drawbacks.

Firstly, the adhesive can fail in cold, damp conditions – the very ones in which your dew shields will be used. Secondly, if the adhesive doesn't fail you may find that, when you undo the shields, both the adhesive and the Velcro fastening are stronger than the mat, which then delaminates. The simplest solution to both of these potential problems is to sew the Velcro tape into place.

Use a good quality polyester thread, which you can find, along with Velcro tape, in most haberdashery or handicraft shops. Don't be tempted to use cotton thread, which absorbs water readily and stays damp for longer, becoming an unwanted source of dampness in your binocular case. It also has a much greater tendency to rot.

This dew shield design is scalable to different sizes of binoculars but, if you're going to scale it up, check beforehand that the material won't sag. For handheld binoculars, which tend to be less dew-prone, you may want to shorten the shield to make it less likely to be accidentally dislodged, but even a short dew shield will enable you to enjoy more binocular observing without the problems of dew.



Step 4

Fit a strong (eg size 100/16) needle to your sewing machine and smear it with a thin layer of vegetable oil. This will prevent the adhesive on the Velcro tape from sticking to the needle and clogging the eye or the groove, which could cause the thread to break.

Step 5

Set the machine to a long stitch length and, if it has the option, a zigzag stitch: a short, straight stitch may cause the mat to easily tear along the perforations. Test your sewing on some offcuts of the mat to ensure that the thread tension is properly adjusted.

Step 6

Sew down each side of the Velcro tape, reversing for three or four stitches at each end. Re-oil the needle at the end of each pass. Trim the loose ends of thread and remove any oil from the needle with a tissue. Your dew shields are now ready to use.

Steady your binoculars with items found around the home

Tips to help you stargaze free of arm fatigue

By Stephen Tonkin

During any binocular observing session there will come a time when you want steadier views than you can get just from holding them, and there won't always be a convenient fence or car roof on which to rest your elbows. While many of those who regularly observe with binoculars have some kind of mounting system, most casual stargazers do not. However, your home can provide some very usable alternatives.

There are many advantages to supporting your binoculars in some way. Close double stars are easier to split; Jupiter's Galilean moons are easier to see when they are close to the planet's bright disc; fainter objects become visible due to their light being concentrated into a smaller area of a non-shaking field of view; and arm fatigue is considerably reduced.

A well-fitting cap with a stiff peak is surprisingly effective at stabilising views when it is gripped while holding binoculars up to your eyes. You will probably find it best suited to smaller binoculars, especially those with roof prisms, which are easier to hold comfortably to the peak. An advantage to this way of supporting binoculars is that it does not limit you to any observing position: it can be used whether you are standing, sitting or reclining.

Strong and stable

If you want more stability, you will need a more rigid option. Essentially you want an item with a pole, so that one end can rest on the ground and at the other there is something to which you can secure your binoculars. Suitable items that you may already have include flat-headed and bow-headed rakes, block-headed push brooms (not besoms or corn brooms), draw-hoes and window cleaners. Brooms and rakes are usually of a length that make them more suitable to seated observing.

Because of their normal use, the end on which you place your binoculars is likely to be dirty, so use something like a small hand towel or tea towel to cover the business end of the tool and protect your equipment.

It's possible to use these tools as simple supports just by resting your binoculars on them, but generally you'll find your makeshift mount easier to use if you secure your binoculars with a bungee cord. The bungee needs to be tight enough to stop the binoculars slipping off, but not so tight that it restricts their freedom of movement, making it difficult to scan a reasonably large region of sky without having to continually reposition the bottom end of the tool. The arrangement shown in Step 2 achieves this but, however you do it, make sure that the tension on the bungee hook pulls it away from you, so that the cord won't whack you in the face if it slips off!

Tools such as window cleaners with telescopic extension poles are much more versatile: they allow you to observe standing up, which offers more freedom of movement, and the adjustable pole length makes it easier to vary the altitude range at

"Tools such as window cleaners with telescopic extension poles make it easier to vary the altitude range at which you are observing"

A folding chair can be used as a sturdy prop in lieu of a permanent alternative

ALL PICTURES: STEPHEN TONKIN

which you are observing. If the binoculars can be angled away from the pole by an adjustable tilt-head, you will be able to observe at very high altitudes without having to tilt the pole much.

Sitting solutions

Home-made binocular chairs often incorporate some sort of supporting frame for either your elbows or the binoculars themselves. Lightweight beach chairs can be used for this purpose, but do ensure that you prevent them from opening in use and trapping your fingers. Bungee cords, cable ties, strips of Velcro, adhesive tape or string can be used for this. Although elbow support is not quite as steady as pole-mounted support, it can be much more comfortable.

Try some of these ideas or, better still, invent your own and see what best suits you. The more steadily you can hold your binoculars, the more likely you are to enjoy using them, and you're also likely to find your observing sessions become much more productive.

TOOLS AND MATERIALS

A combination of the following

A cap with a stiff peak; a block-headed push broom; a flat-head or bow-head garden rake; a window-cleaner with a tilt-head and a telescopic extensible pole; a fold-flat beach chair or some other folding chair; a clean tea towel, duster or small hand towel; a selection of bungee cords.

STEP-BY-STEP

Step 1

A cap with a stiff peak makes a simple, portable binocular support that's best suited to smaller binoculars. Simply make sure that your cap is firmly on your head and 'sandwich' the peak between your fingers and the top of the binoculars.

Step 2

If you're going to use a broom or a rake as a support, it's a good idea to cover the business end with a cloth, such as a clean hand towel, tea towel, jay cloth or duster. This will prevent any dirt from being transferred to the binoculars.

Step 3

Because of their length, tools like rakes and brooms are best suited to seated observing. For safety and ease, use a bungee cord to secure the binoculars to the covered end of the tool being used. This will give you greater freedom of movement.

Step 4

A long window cleaner is very versatile. The telescopic handle can be easily altered for height, and the adjustable tilt-head holds the binoculars away from the handle, enabling you to get underneath the binoculars so that you can observe objects at high altitudes.

Step 5

A folding chair is often the ideal width to use as an elbow rest. Use a bungee cord, Velcro strap or similar to stop it from opening and trapping your fingers. If you are observing in a seated position, simply place the chair across your lap.

Step 6

A folding chair is also useful on a recliner, so long as the recliner has sling-type arms. In this case, put the folded chair across the arms and rest your elbows on it. You can easily change elevation by slightly changing your position or the angle of the folded chair.

Turn a coffee container into a dew shield

Transform an everyday object into one of the most vital astronomy accessories

By Ben Kent

You're out observing on a clear evening but you notice bright stars growing dim, the sky looking misty and, ultimately, hardly anything can be seen at all. Your telescope has radiated its heat to the sky and the lens has dropped to below the dew point. Water vapour has condensed on your lens and shortened your observing session. Irritated, you call it a night.

Dewing is an issue that most observers face, with refractors and Schmidt-Cassegrains being most prone to dew forming on the front lens. This can be eliminated using a dew heater, but a cost-effective alternative is to use a dew shield. This is a tube that slides over the end of the telescope, insulates the front lens and prolongs your observing time. Again, these can be purchased, but they're also simple to make using little more than a catering-sized coffee container and some neoprene.

A 750g/1kg coffee container is perfect for this project, particularly because this size of container is so robust, but you'll need to find one with a diameter that roughly matches your telescope. Ours came from a canteen, but you could also ask a local café or restaurant if they have any that they're going to be throwing away. Adhesive-backed neoprene on both the inside and outside of the container provides insulation and a barrier to water vapour – if your container is cardboard this will prevent it from becoming soggy. The neoprene also helps the dew shield fit snuggly over the telescope tube and, being black, prevents any reflections on the inside.

TOOLS AND MATERIALS

Materials
750g/1kg coffee container to fit your telescope, 6mm self-adhesive neoprene, 3mm self-adhesive neoprene.

Tools
Craft knife, scissors, metal file, fabric tape measure, black duct tape or electrical tape, marker pen.

Repurposing the pot

Start by removing the base of the container, carefully cutting around the interior rim using a craft knife. Take care to keep as close to the rim as possible and not to squeeze too hard as you cut, otherwise you may distort the tube. Once the base has been removed, file off any sharp edges so you can't injure yourself or rip the neoprene. Measure the outside of the container and make a note of the circumference, then cut the neoprene to that size. This ensures that the neoprene will wrap completely

▲ The finished dew shield is black on its inner surface to reduce unwanted reflections

ALL PICTURES: BEN KENT

around the container.

Remove a small portion of backing from the neoprene and stick down the end on the outside of the container, ensuring the edge is flush with the rim. We found that removing a bit of backing and sticking that bit down is the most effective way as the adhesive is strong. Doing it like this also allows you to make adjustments as you go along. Trim off any excess neoprene that sticks over the rim, then cut an additional strip of neoprene and use it to cover the seam.

You'll need to measure the inside circumference of the container and then cut your neoprene to match. The length of internal neoprene should be in the region of 20mm less than the length of the container. Carefully apply the neoprene to the inner surface just as you did before. Lining the inside can be awkward, so you may find it easier to cut this piece of neoprene into several panels and attach them sequentially.

"Catering-sized coffee containers are perfect for this project and are suitably robust, but you'll need to find one with a diameter that matches your telescope"

Coffee containers have a rim into which the lid fits. You need to push the neoprene up against this when lining the inside, leaving a gap at the other end. Fill this gap with thinner neoprene to create a ridge for the telescope tube to rest against. Cut a shorter length of neoprene to cover any seams where the ends meet. The final step in the process is to wrap the outside of the dew shield with either black electrical tape or black duct tape to give the neoprene a little extra protection from nicks and tears.

An extension of the project would be to combine it with a dew heater band built into the rim. This ensures that your optics will remain clear for the duration of an observation session, as even with a dew shield the lens will eventually mist up.

STEP-BY-STEP

Step 1

Use a craft knife to make a slit in the base of your container at the edge of the rim. Carefully slide the knife around the rim to cut out the base. File off any sharp edges so you don't cut yourself or damage the neoprene later on.

Step 2

Measure the exterior circumference of the coffee container with a tape measure and make a note of its size. Next, cut a piece of 6mm neoprene to encompass that circumference and check that it wraps completely around the container.

Step 3

Peel off the neoprene's backing as you go and wrap the self-adhesive side around the outside of the coffeee container, keeping the edge flush with the rim. Cut a strip of 3mm neoprene the same length as the container and use it to cover the seam.

Step 4

Measure the internal circumference of the coffee container, then cut a piece of 6mm neoprene to match and divide it into smaller panels. Next, cut a strip of 3mm neoprene to the same circumference to fit the 20mm gap between the neoprene and the end.

Step 5

Attach the 6mm neoprene panels to the inside of the container, pushing it up to the top lip, then fix the 3mm neoprene over the gap between the bottom rim and the thicker neoprene. Again, cover the seam using 3mm neoprene.

Step 6

Wrap either black electrical tape or duct tape around the outside of the dew shield, taking care to ensure that there are no bubbles or else the tape covering will lift. This gives it a neater finish and also protects the neoprene from damage in use.

BIG BUILD

With an easily adjustable seat, this chair can be used with all manner of scopes, and by big and small kids alike

Make an OBSERVING CHAIR

By Mark Parrish

Say goodbye to wet knees and aching joints with this DIY project – an observing chair that folds flat for easy storage

MARK PARRISH X 7, ISTOCK

Observing a well-placed object in the night sky is always a pleasure, but if the object is low on the horizon or close to the zenith, you may find you have to kneel on damp ground or crane your neck to get your eye close enough to the eyepiece. It's at times like these when an adjustable observing chair really comes into its own.

This wooden chair is a practical and attractive solution, with an adjustable seat that can be positioned anywhere between 150mm and 920mm off the ground. This height range should be ideal for most amateur scopes, but there's no reason why the design couldn't be extended a bit. You could even have kids stand on the platform – perfect for those 'small child, big Dob' moments.

You can make this observing chair with a basic tool set and minimal woodworking skills, but if you own (or can borrow) an electric or pillar drill, and an electric jigsaw or scroll saw, you will be able to speed up the process – and perhaps ensure a bit more accuracy.

All of the materials you need can be easily obtained from most timber merchants or DIY stores. If you are lucky, you may be able to get the main parts cut to size for a small charge in the store when you buy the wood, leaving just the fiddly bits to deal with yourself.

Portable solution

The chair is based on one created by Canadian amateur astronomer Ed Hitchcock – which itself borrows from some commercially made examples – so its design is well evolved, and includes a number of features that will enhance your observing experience. For example, the chair can be folded flat for storage. If you want to take it anywhere by car, you can easily unscrew the spreader leg, which makes it small enough to fit across the back seat. ▸

"You can make this observing chair with a basic tool set and minimal woodworking skills, but an electric drill and jigsaw will speed the process up"

STEP-BY-STEP

Step 1

Accurate marking out is the key to success. Several parts are made in pairs, so tape them together, mark them and cut them at the same time. That way, even if the outcome is a little inaccurate, at least the two sides will be symmetrical.

Step 2

The notched racks that the seat slots into are easier to make than they look. Clamp the two pieces of timber together and drill holes every 50mm along the joint. Mark the top of each piece before you separate them, so the notches always match up.

Step 3

Some parts, like the support brackets and seat brackets, need to be shaped. You can cut them using a coping saw or, preferably, an electric jigsaw or scroll saw. Again, tape the two bits of wood together and cut, drill and sand them at the same time.

Step 4

After cutting the plywood panels and timber rails, use waterproof wood glue to stick them together. Reinforce with woodscrews through pre-drilled and countersunk holes. NB it's easier to drill through plywood and screw into timber than the other way around.

Step 5

Assemble all the parts you've prepared to check for fit and ease of movement. Dowels may need to be sanded or have spaces cut for them to allow free movement, so it all folds down flat. Don't paint the chair while it's assembled, or the parts will stick.

Step 6

Mount the spreader leg so that the support section is held just above the ground. We used wing nuts and screws so it can be removed for transport. Screwing in a block above the leg provides extra strength. Varnish or paint the parts before reassembly.

The completed observing chair can be partially dismantled, which makes it easy to store, transport and carry

"You could attach a rail to the side for children to hold on to if they are standing on the seat, or add an accessory tray to hold your eyepieces"

▸ For our seat we chose to fix the spreader leg to the rear support because this makes it easier to fit the front of the chair between tripod legs.

Apart from the woodscrews, all the parts are made from timber. The pivots are made from 25mm wooden dowels, which can be found in most DIY stores, though you could also use an old broom handle. You will need a drill bit to match this dowel, and sometimes a little sanding or filing is required for a nice fit. However, it isn't too tricky to make a strong and accurate chair.

If you use plywood for the seat brackets, we recommend gluing two pieces together for each side to give them extra thickness – though we were lucky enough to find some hardwood (ash) in our offcuts box for these, which added a touch of quality. If you have access to hardwoods and wide natural boards, you can substitute them for the softwood and plywood parts. This improves the durability and also allows a degree of customisation. In any case, avoid using MDF or chipboard as these materials can break down when they become damp and get knocked about.

Using the chair is straightforward. Once the spreader leg is fixed on, simply unfold the rear support and the brace will drop into place, securing the shape. The seat can be raised and lowered easily, but once you sit on it, it locks into position and cannot drop down.

There are a number of additions you may want to consider. If you are planning on using the chair for long sessions, you could add a footrest for extra comfort or a second seat for a friend. You could attach a rail to the side for children to hold on to if they are standing on the seat, or add an accessory tray to hold your eyepieces.

However you decide to build your chair, it will be an invaluable observing companion for many years to come – unless you use MDF, of course.

TOOLS AND MATERIALS

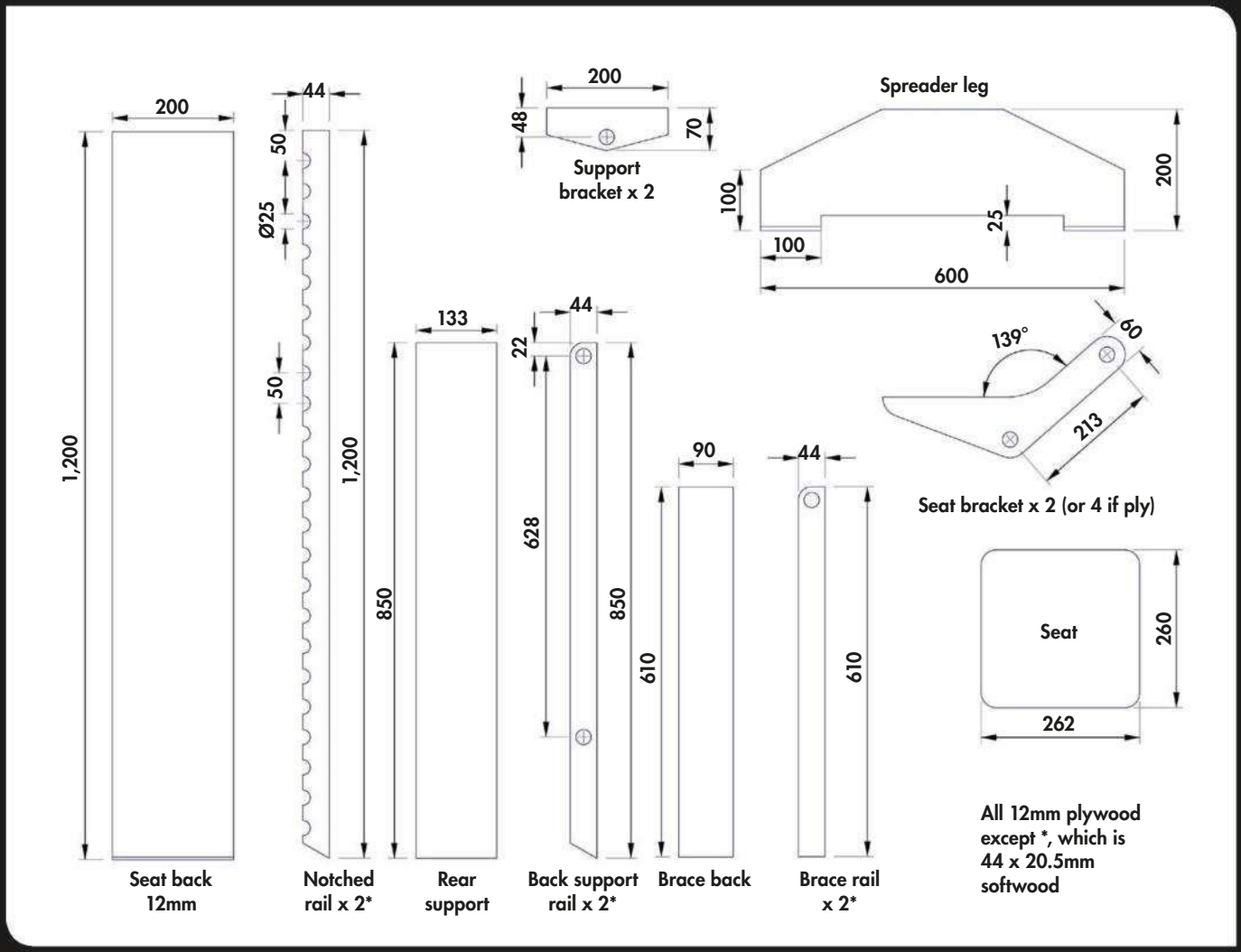
Finishing
Treat the timber with varnish, preservative wood stain or exterior paint. The choice of colour is up to you, though bear in mind that lighter colours are easier to spot in the dark.

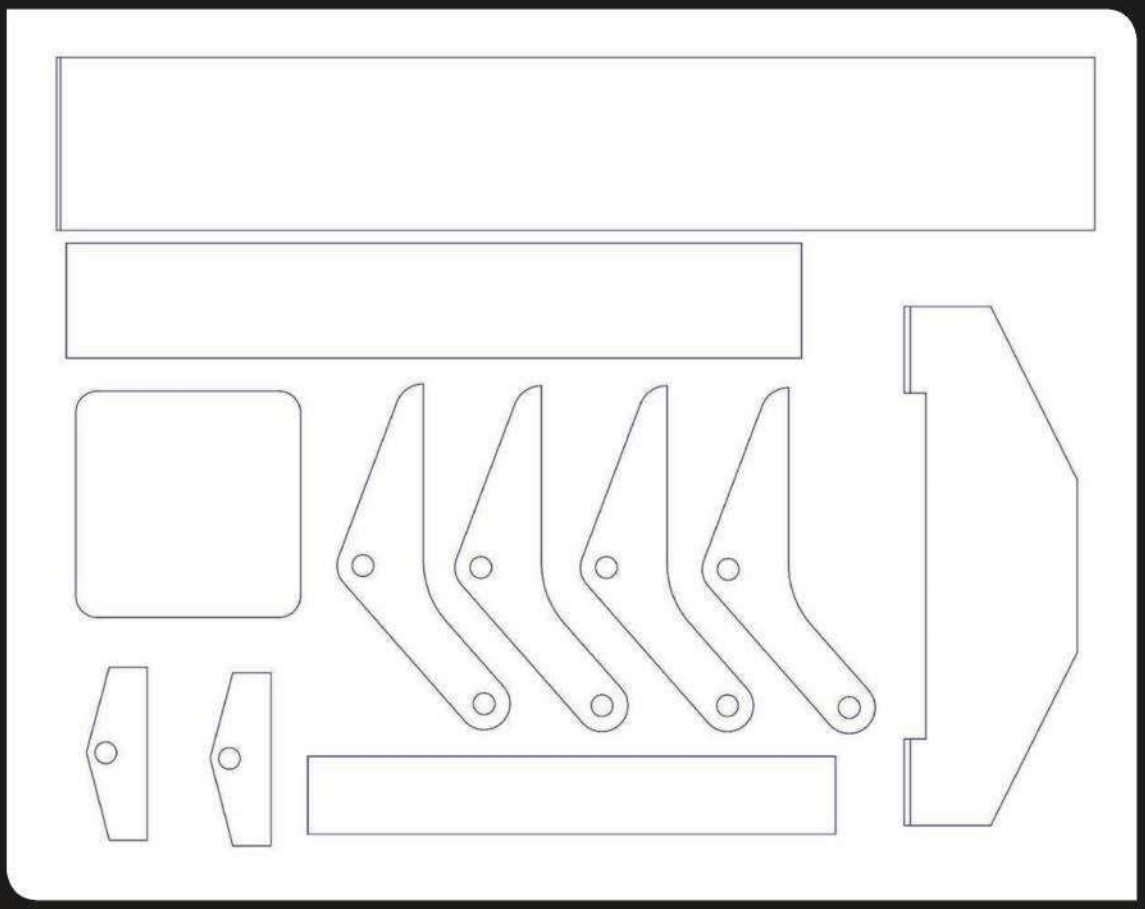
Sundries
Thirty 25mm No 8 countersunk screws, waterproof PVA wood glue, two M6 x 40mm bolts and wing nuts.

Timber
All of the plywood parts can be cut from one 1220mm x 1220mm piece of 12mm-thick board. You also need two 3m lengths of 44mm x 20.5mm softwood. For the pivots, cut up a 500mm length of 25mm dowel (or broom handle).

Tools
Coping saw, jigsaw or scroll saw; electric or pillar drill with 4.5mm, 25mm (to suit dowel) and countersink bits; G-clamps, screwdriver.

MARK PARRISH X 3, ISTOCK X 4





▲ The parts you'll need to build your observing chair

◄ Suggested layout to fit all the parts in one 1220 x 1220mm piece of plywood

MORE ONLINE

Print out these plans at their correct sizes and find extra images

Having trouble finding low planets in the twilight? The sky ruler is just what you need

Make a sky ruler

By Mark Parrish

This simple instrument will help you locate and describe the position of objects in the night sky

ALL PICTURES: MARK PARRISH

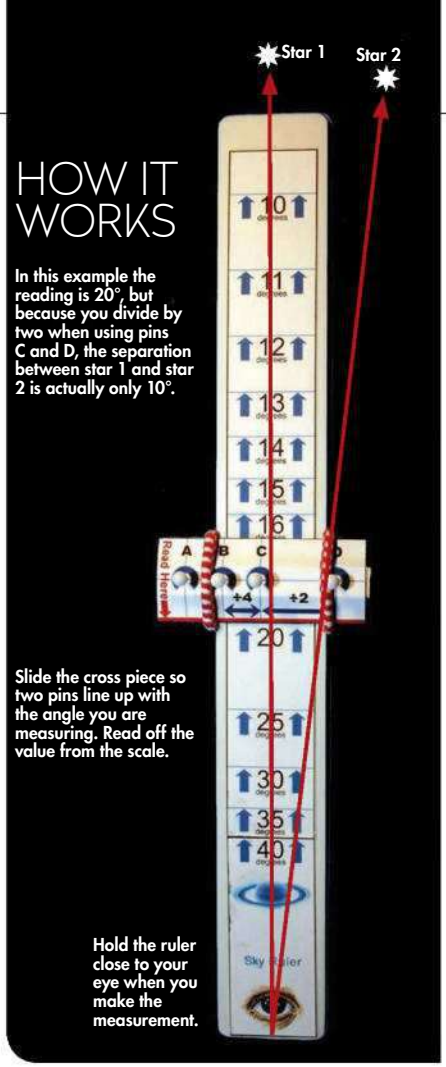
The sky ruler is a simple but effective device that helps you find objects in the sky and make measurements of their positions. It's also easy to make from everyday items.

The sky ruler's design is based on an ancient tool called a cross staff, which is thought to have originated around 400BC having evolved from instruments used by Arab navigators. A cross staff was used to calculate someone's latitude because it can measure the altitude of the Sun at noon.

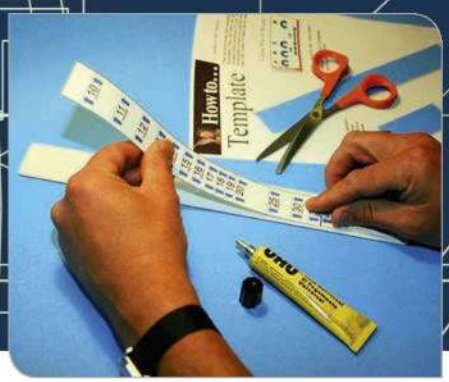
Use your illusion

The objects we see in the night sky appear to sit on the inside of an dark sphere with our planet at the centre. The stars seem to be stationary while the Sun, Moon and planets look like they move around us. This is, of course, an illusion, but we can nevertheless use this misunderstanding to describe the positions of celestial objects in terms of angles measured around the inside of this imaginary sphere.

You can use your sky ruler to determine the angles that separate objects in the sky,


HOW IT WORKS
In this example the reading is 20°, but because you divide by two when using pins C and D, the separation between star 1 and star 2 is actually only 10°.
Star 1
Star 2
Slide the cross piece so two pins line up with the angle you are measuring. Read off the value from the scale.
Hold the ruler close to your eye when you make the measurement.

STEP-BY-STEP

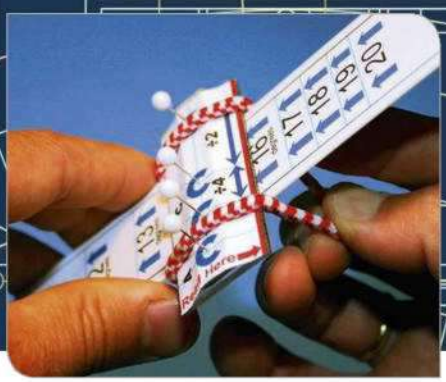


Step 1

Print the sky ruler scale from the bonus content (www.skyatnightmagazine.com/bonus content), carefully cut out the three sections and glue the first section to the flat side of a ruler so that the eye symbol is at the end. Add the remaining part of the scale.

Step 2

Cut a 7cm (2.75 inches) long cross piece from a different ruler using a junior hacksaw. If it's plastic, glue a lollipop stick to the upper curved surface. Stick the cross piece's paper scale on top using glue. Covering the scales with clear tape makes them more durable.



Step 3

Push the four map pins into the positions marked on the cross piece. Use the hair band to hold the cross piece on the ruler. The cross piece should be secure, but easy to slide, so you may need to experiment with different-sized bands.

as well as their altitude above the horizon. These measurements not only improve the accuracy of your observations but they also allow you to describe the things you've seen to other astronomers. After all, "Mercury is quite low over there" isn't as informative as "Mercury is 15° above the southwestern horizon."

By setting the sky ruler to predetermined angles, it can also help you locate objects described in star charts. Or, if you have planetarium software on your computer, use the software to display the altitude and azimuth values for an object, and then use your sky ruler to find it in the night sky. Alternatively, you could use a celestial positions calculator to get the altitude and azimuth values for an object. These values, which are measured in degrees, vary with time, so unless you have the computer by your telescope you'll need to adjust the calculations to match the time and date of your observations.

The azimuth value tells you the direction to look in. Due north is 0° (or 360°), 90° is east and so on. A compass is obviously useful for this, although if you can see Polaris (found by following a line from Merak and Dubhe, the 'pointers', in Ursa Major), you can estimate where north is and work out where to look from there.

The altitude tells you how high to look in the sky; it's measured from the horizon up. The horizon is 0°, while 90° is directly overhead (the zenith). The sky ruler measures angles from 2.5°–40°. To locate your object you set the sky ruler to the altitude given by the computer and aim it in the azimuth direction. If your object is too dim for the naked eye, you'll at least know where to point your binoculars or telescope's finderscope.

While not quite pocket-sized, the sky ruler is easy to slip into a telescope case and is surprisingly accurate. But if you want even more precision and enjoy the challenge of building a good quality instrument, why not scale things up? The original cross staffs were about a metre (3.3ft) long and made from hardwood. If you'd like to recreate one, you can find dimensions for the scale graduations on sky rulers of varying lengths in the bonus content online.

A sky ruler may not be a match for a Go-To telescope mount, but it's a great aid to finding your way around the night sky.

MORE ONLINE

Print out the sky ruler's scales and a dimensions calculator

TOOLS AND MATERIALS

Hair bands & lollipop stick

If you use plastic for the cross piece you'll need to add a strip of wood (a lollipop stick) to the top. This provides a layer to stick the pins into. Use two hair bands (the kind made with round elastic) to hold the cross-piece and main scale together. Alternatively you can use rubber bands.

Map pins

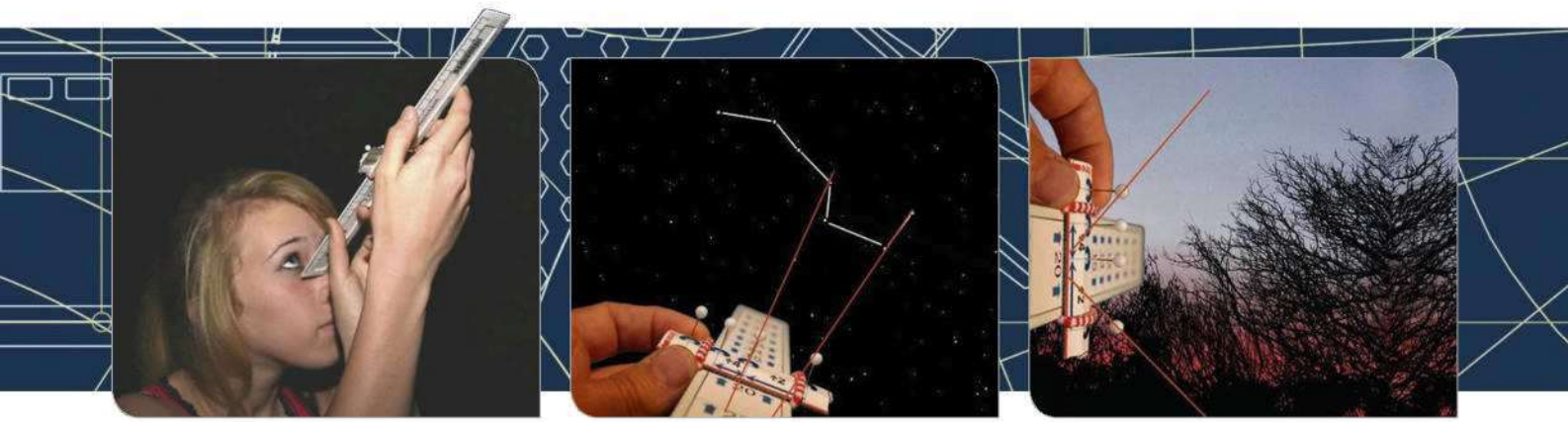
For the sights you need to use four map pins, the kind with plastic beads on the top. White pins are easier to see at night, so consider painting the tops white if necessary.

Rulers

You need a 30cm (12-inch) ruler for the main scale. This could be made of plastic or smooth wood. To make the cross piece you need a short piece of another ruler 7cm (2.75 inches) long. Alternatively, a strip of wood or plastic could be used.

Tools

A craft knife or scissors to cut out the printed sky ruler scale (which you can find in the bonus content online), a junior hacksaw to cut the cross piece to size, glue or double-sided tape to stick down the printed scale and lollipop stick.



Step 4

To measure an angle, hold the sky ruler up to your eye with the end touching your cheekbone. Now move the cross slider so a pair of pins line up with the angle you're measuring. Try working out the length of the Plough in degrees.

Step 5

Note where the cross piece lies on the scale. If you used the outer pins (A and D) you can read off the angle directly. If you used pins C and D, divide the reading by two; for B and C, divide by four. This part of the Plough is 10° across.

Step 6

If you know the altitude and azimuth of an elusive object, set the cross piece to the desired altitude and, with the cross piece held vertically, aim in the azimuth direction. If one pin lies on the horizon, the corresponding pin should be close to your target.

Make a spectroscope

Discover the chemical make-up of the Sun with this easy-to-build device

By Mark Parrish

Create a spectroscope with materials in your recycling box, using a CD to create a visible spectrum of a light source (inset)

Spectroscopy is an amazing science that allows you to discover what stars are made of by studying the light that they give off. And you can do this cheaply and easily by building your own spectroscope.

You can make a spectroscope from the sort of everyday materials you find in your recycling box. The design we've used has a narrow slit at the front that concentrates a beam of light from the source you're studying onto the surface of a compact disc. When the light hits the CD it's split, which produces a reflected spectrum that you can view by looking into the eye tube.

This spectroscope reflects just a small fraction of the Sun's light from a narrow beam, and is safe to use. You should never look at the Sun directly with your naked eyes or through a telescope or binoculars as you can very quickly do permanent damage your eyesight.

The science behind the spectroscope helps us understand one of nature's most beautiful phenomena: the rainbow. When white light from the Sun is reflected by thousands of tiny raindrops we see a rainbow – a continuous spectrum of colours from red at one end to violet at the other. These colours are spread out because tiny, individual reflections from each raindrop overlap and interfere with one another, causing radiating patterns of bright light. The corresponding patterns appear at slightly different angles because the wavelength of each colour of light is different, which causes the colours to separate out in an effect called diffraction.

CDs have thousands of tiny reflective spots on them that are normally read by a laser when you play them. Used in this spectroscope these tiny spots reflect the light in the same way that raindrops do so you can create a rainbow of your own.

Excited molecules

So how does splitting light into its different wavelengths help us figure out what elements created it? Well, light comes from molecules that have been heated or electrically excited. If the molecules are far enough apart – as they are in low-pressure gases – their atoms give off defined wavelengths of light that appear as bright, narrow lines when they're separated out by a spectroscope.

This is called an emission spectrum. No two elements give the same spectrum so it's possible to identify the elements that make up an excited gas by studying its spectrum. For example, a traditional street light, in which the light comes from sodium vapour, emits two yellow lines that are very close together, with wavelengths of 5,890 and 5,896 Ångströms. An Ångström is the unit used to measure the distances involved in wavelengths of light.

Light from hot solids, liquids and high-pressure gases is a continuous spectrum because their atoms are closer together and they interact. This means all wavelengths are emitted, giving the kind of white-light 'rainbow' spectrum, just like we see when we observe light coming from the Sun's surface or photosphere.

But if you use your spectroscope to study the Sun's spectrum more closely, you may notice some darker lines. Known as Fraunhofer lines, these are caused when white light from the Sun's photosphere passes through a layer of relatively cooler

TOOLS AND MATERIALS

Card
An A4-sized sheet of stiff card. If you are buying it, black is a good choice of colour. An environmentally friendly alternative is to use card from old packaging, such as a shoe box.

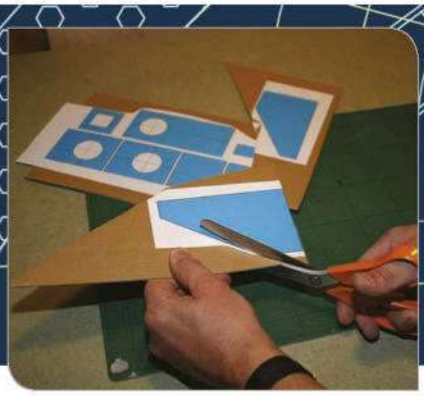
Cardboard tubes
For the main tube, the best thing to use is the centre of a roll of kitchen foil. If you're struggling to find one, you could roll up some thin card instead. The eye tube is a short length of similar material.

Compact disc
Any regular data or music disc works, even if it's scratched or damaged. You can tell it will work if it produces a rainbow reflection when you hold it near a light.

Tools tape and glue
Use a craft knife or scissors to cut out the printed spectroscope template, which you'll find in the bonus content at www.skyatnightmagazine.com/bonuscontent, and the cardboard. A hot-melt glue gun is a inexpensive tool for this kind of project, but you can also use glue or sticky tape to join the cardboard together. Black electrical tape is great for covering gaps and making the slit at the end of the main tube.

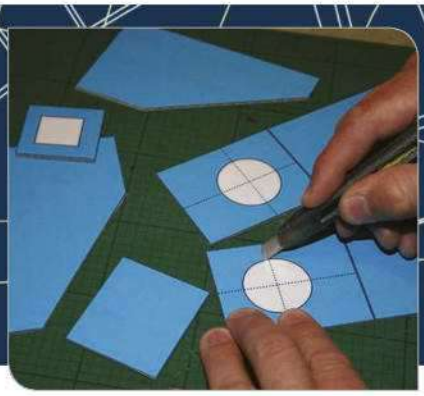
ALL PICTURES: MARK PARRISH

STEP-BY-STEP



Step 1

Print out the spectroscope template from the Bonus Content online and stick it to your card. Cut round the six sections. If your tube has a different diameter to the markings on the template, draw round it using the dotted lines to keep it central.

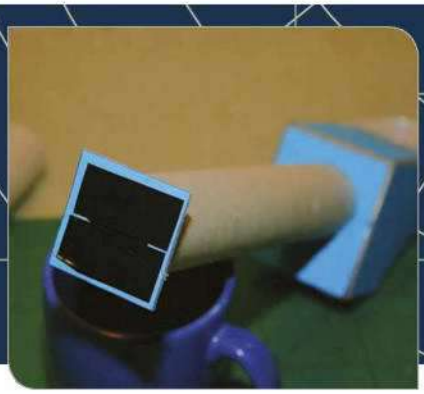


Step 2

Carefully cut out the holes in the card parts. Take care with the craft knife; cut through the card a bit at a time. You can trim the edge of the hole once you have completed the cut. Score along the two fold lines to help make an accurate fold.

Step 3

Glue or tape the rectangular folded sections onto one of the sides. Push the main tube through the two holes. When you're happy with the construction, fix the second side and the eye tube on. Glue the slit frame onto the end of the main tube.



Step 4

Stick two pieces of black tape side-by-side to make the slit. Experiment with the gap between them, but about 0.5mm is a good distance to start with. Finally, fix the CD to the top half of the sloping edge with black tape. Use the tape to seal any gaps.

Step 5

The personal spectroscope can be hand-held or mounted on a tripod with tape or a rubber band. Point it at a light bulb to check the spectrum. Examining the Sun requires a steady hand but you should be able to produce a good spectrum.

Step 6

Once you've mastered the basics, try imaging the spectrum. A tripod is crucial for this because you'll need both hands to hold the camera up to the eye tube. Try to identify the two distinctive yellow sodium lines produced by most street lamps.

gases in its atmosphere, called the chromosphere. These gases absorb exactly the same wavelengths of light as they emit. Although they do emit some light as well, they're silhouetted against the much brighter background and the lines appear dark. By examining these lines it's possible to detect the chemical make-up of the Sun's atmosphere. There are lines for hydrogen, magnesium, calcium and sodium, to name just four.

Read between the lines

Fraunhofer lines are quite tricky to see but emission lines from gases are easy. Try examining light sources around the house; traditional light bulbs with tungsten filaments produce a continuous spectrum from the glowing solid metal, while low-energy bulbs and tubes produce beautiful coloured lines.

Once you've mastered the basics with your spectroscope you could try to photograph your spectra by holding a digital camera up to the eye tube. A little experimentation with focus and exposure is required to get the best results. Obtaining an image of the Fraunhofer lines in bright sunshine is a big challenge.

If you enjoy taking your first steps into spectroscopy you can easily take things further. Many amateur astronomers use small diffraction filters between their scopes and cameras to analyse the spectra of distant stars; the light-gathering properties of a telescope make this possible. Computer software can be used to examine the absorption spectrum image, revealing the chemical composition of the star's chromosphere.

It was by examining the combined spectra of stars in distant galaxies that professional astronomers concluded that the Universe is expanding. They found that the stars were all moving apart and their spectra was slightly shifted towards red wavelengths. This phenomenon occurs when an object is moving away from us. Known as the Doppler Effect, it becomes more pronounced the faster the object is moving, just as the tone of a police siren changes as it speeds past.

Spectroscopy is an area where amateur astronomers can do some real science. Who knows, your personal spectroscope may herald a great discovery.

MORE ONLINE

Find and print the plans for the spectroscope at www.skyatnightmagazine.com/bonuscontent

The red-light torch can be held in a wooden stand and positioned over star charts

Make a red-LED torch

By Mark Parrish

Construct this red-light torch to check star charts without spoiling your night vision

One thing all astronomers need to do is find their way around in the dark. That task becomes a lot easier if you have a red-light torch, which is a tool that's very easy to make using a red light-emitting diode (LED). You don't need any electronics expertise or soldering skills because you can use 'chocolate box' terminal blocks, that can be connected up with just a screwdriver. And although some of the components are quite small, they're easy to work with and don't require any special handling.

The torch doesn't have a casing as such – it's really just a small cluster of parts that, once connected and checked, are held together with glue and sit on top of a snap-on battery connector. The resulting torch assembly can be clipped onto any standard PP3 9V battery – the square type found in household smoke detectors – and will provide you with many hours of useful red light. And as the completed torch isn't much larger than the battery, you can easily keep it stored in one of your eyepiece boxes or a jacket pocket.

"The components required to make the torches are readily available from electronics suppliers and are relatively inexpensive"

The step-by-step guide opposite explains how to make a standard hand-held version of the torch, but with a little ingenuity you can customise the design to meet a variety of needs. A bright red LED version is useful for finding your way around in the dark and searching for dropped items. By fitting self-adhesive Velcro pads, you can attach your torch to different parts of your setup for hands-free illumination. A lower-powered, red LED version, attached to a simple wooden stand, is invaluable for reading sky charts or sketching. By using flashing red LEDs you can make effective, eye-catching warning lights. These can be attached to the feet of your tripod or boxes of equipment to prevent you and anyone else from tripping over them.

The red light produced by these LEDs is invaluable to astronomers since it doesn't spoil night vision – when your eyes become accustomed to low light levels and can see fainter objects. There are two types of sensor cells in your retinae – rods and cones. The rods pick up low light levels and become extremely sensitive when you've been in the dark for a while.

It can take up to 20 minutes for your eyes to become fully adapted to the dark. Sudden bright light sources, such as normal

TOOLS AND MATERIALS

Electronic parts

For each torch you will need: one section (four pairs of terminals) of connector block; one LED (bright red, dim red, flashing red or 'ultra bright white', depending on use); one resistor (330 Ohm); one battery (PP3); one snap-on battery connector and one slide switch (or a piece of paper clip for a permanently on version).

Glue

A hot-melt glue gun is ideal. Alternatively, use epoxy resin.

Tools

You need a small screwdriver, a craft knife for stripping wire (or wire strippers if you have them) and a small pair of pliers for bending the legs of components.

ALL PICTURES: MARK PARRISH

▲ You could also attach one of these torches to your tripod legs to avoid tripping over them

white-light torches, car headlights and camera flashes spoil this adaptation. But red light has virtually no effect on your rod cells, so red torches and warning lights don't spoil your night vision.

Red, white and flashing

The components required to make the torches (LEDs, switches and resistors) are readily available from electronics suppliers and are relatively cheap. If you make several torches – either for yourself or perhaps for friends in a local astronomical society – you can buy the parts in larger quantities, which might bring costs down even lower.

By buying a few different LEDs you can use the wiring diagrams in the bonus content (at www.skyatnightmagazine.com/bonus content) to make six lights in total – one bright red torch, three flashing warning lights for each tripod leg, one red chart-reading light and one ultra-bright, white LED to make a 'conventional' torch to use when you're packing up your kit at the end of the night.

It would be more accurate to describe the design we've used as practical rather than aesthetically pleasing, but in just a few minutes you can create a useful set of lights for a fraction of the price of the commercial alternatives – and use them without affecting your night vision.

MORE ONLINE

Find a wiring diagram and more build photos

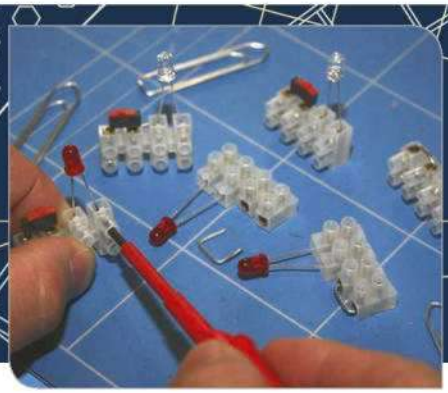
STEP-BY-STEP

Step 1

Use a craft knife to cut the connector blocks to size. Each piece should be four pairs long. Trim back the casing on one side of the right-hand pair to accommodate the short legs of the switch. Take care and cut away from your hand, not towards it.

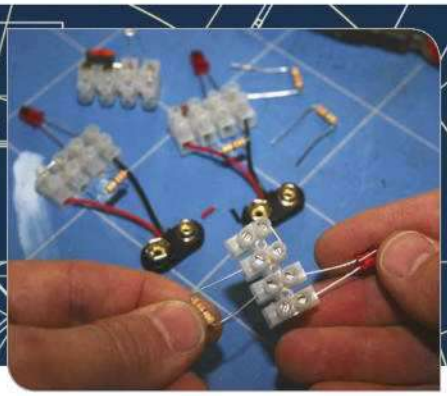
Step 2

Use pliers to bend the legs of the switch so they fit into the block. The middle and one outer leg are used; bend the other, redundant, outer leg flat. For flashing warning lights use a cut and bent piece of paperclip in the block, instead of a switch.



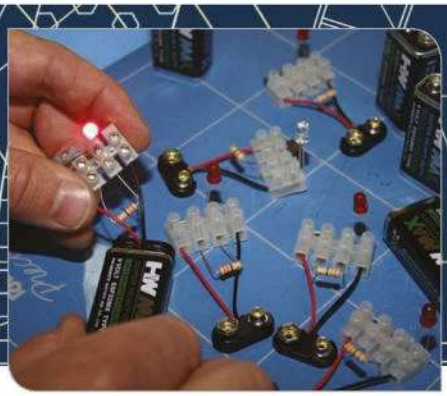
Step 3

Use a small screwdriver to connect the switch/bent paperclip and LED to the trimmed side of the block. The redundant switch leg faces towards the middle of the block, as does the slightly longer, positive, leg of the LED. LEDs only work one way round, so check carefully.



Step 4

Trim the battery connector leads to 55mm and strip about 10mm of insulation. Attach the resistor and connector to the opposite side of the block; the resistor bridges the central pair (any way round); the battery connector's red wire goes on the left, opposite the switch.



Step 5

Before gluing it all together, connect it to a battery and check that the torch works. The switched versions can be turned off; the flashing warning lights are always on when connected. If nothing happens, check for loose wires or LEDs round the wrong way.

Step 6

Glue the battery connector to the base of the connector block then bend the LED into position and push the resistor down between the screw sleeves. Check it again, then fill any gaps with glue, avoiding the switch. Mask the LED and switch and paint if you wish.

SOLAR OBSERVING

Our nearest star is a fascinating target to observe since it can change in real time, yet care must be taken. The projects we show you how to put together here will produce devices capable of showing the Sun in complete safety

BACKGROUND IMAGE: ISTOCK, PETE LAWRENCE, MARK PARRISH, STEPHEN TONKIN

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36 Make a simple solar finder

Make a white light filter

WARNING
Do not look directly at the Sun with the naked eye or any unfiltered optical instruments

By Pete Lawrence

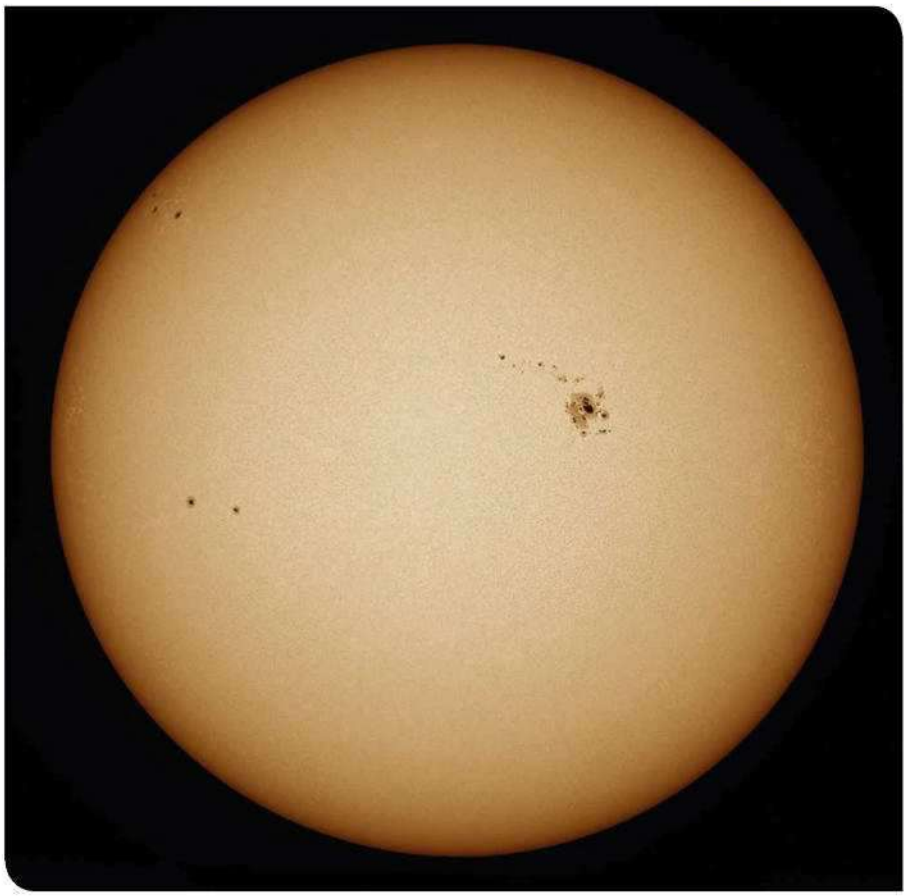
You don't need a dedicated solar scope to explore our parent star

The Sun is a very gratifying object to observe. It is dynamic, with features that sometimes appear to change over the course of just a few hours. It is also rather convenient in that you can only observe the Sun during the day when it is generally warm – this is the comfortable side of astronomy!

Being so close, our star offers us a unique opportunity to study a stellar body in detail. However, this closeness also carries danger with it, so you need to be very careful when attempting to view the Sun through a telescope. There are various ways to do this, but the safest is to fit a full-aperture white light filter over the front end of your telescope tube. The term 'white light' means that you'll see the Sun as it is normally, but filtered and greatly dimmed to protect your eyes. The resulting view has good contrast and neutral colour.

These filters can be bought ready-made, but they are relatively simple to make yourself using sheets of solar film cut to size. Baader Planetarium's AstroSolar film is available in two grades:

ALL PICTURES: PETE LAWRENCE



▲ A white light filter reveals the majesty and wonder of the Sun without risking your eyesight

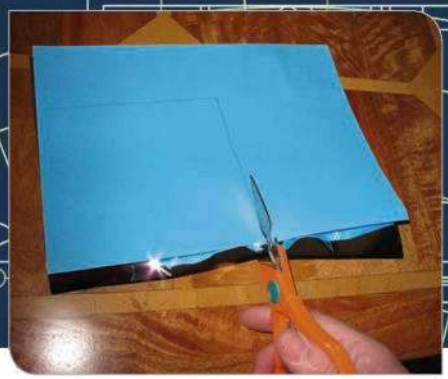
STEP-BY-STEP

Step 1

Mark a piece of card into 50mm-wide strips, then cut them out and tape them together end to end to form one long strip. Your combined strip needs to be long enough to wrap around your telescope tube at least three times.

Step 2

Place double-sided tape at regular intervals on one side of your card strip. Wrap the strip around the tube, tape facing outwards – the tape will stick it all together, creating a ring. Don't make this overly tight as you'll need to slip it on and off the telescope.



Step 3

Measure the outer diameter of your telescope tube. Sandwich the solar film between two pieces of thin card and mark a square with sides equal to the tube diameter plus 2.5cm. Cut out this layered square, then remove any protective backing from the film.

TOOLS AND MATERIALS

Card
An A2 sheet of thin, bendable card cut into 50mm-wide strips forms the filter's slip-on wall.

Ruler and pencil
Essential to ensure you mark out the card and solar film to the correct size, making the filter safe to use.

Scissors
Make sure they are sharp so you don't damage the solar film as you cut.

Sticky Tape
Both normal and double-sided tape are invaluable for easy construction.

Solar Film
The main filter material is generally available in A4 sheets, but is sometimes available in larger rolls.

OD 3.8 is for imaging only, while OD 5.0 is suitable for visual observing and imaging. OD stands for 'optical density' – the higher the number, the dimmer the image. Thousand Oaks Optical also supply solar film in sheets.

Creating the filter will take about an hour. In addition to the solar film, you'll also need some thin card, sticky tape and double-sided tape. Once built, your solar filter will be able to convert a regular astronomical telescope into one suitable for white-light solar viewing. It's worth checking the filter for pinprick holes and tears each time you're about to fit it. To do this, simply hold it up to the Sun and inspect it visually. If you do find any, don't risk it – discard the filter and make a new one.

If your telescope aperture is too big to entirely cover with solar film, make a mask from stiff card to cover over it; cut a smaller hole in this mask and cover that with solar film. Make sure that the mask fits over the entire aperture and that no light can leak around its edges. For scopes with a central obstruction, such as reflectors or Schmidt-Cassegrains, cut the aperture hole off centre so the secondary mirror doesn't block it.

Once the filter is fitted, you're ready to view the beauty of the white light Sun.

"Once the filter is fitted, you're ready to view the beauty of the white light Sun. You'll see dark sunspots and bright faculae embedded within the shaded edges of the Sun's disc"

Cap your finder

When you use the filter, it's important to remove or cap your telescope's finder. This prevents it from being damaged by the Sun's intense rays and also removes the urge to look through it to line up the main instrument! Always make sure that the telescope is pointing away from the Sun before fitting the filter. When you're done observing, do the same – aim the telescope away from the Sun before removing it.

With it, you'll see dark sunspots and bright faculae embedded within the shaded edges of the Sun's disc, a real effect known as limb darkening. Sunspots generally occur in groups or active regions. A typical sunspot has a dark inner area, the umbra, surrounded by a lighter one, the penumbra.

The visible surface of the Sun is called the photosphere. A 6-inch telescope should reveal it has a fine, rice-grain pattern called solar granulation. This represents the tops of vast energy-transferring convective cells working beneath the Sun's surface.

Keeping a daily record of the Sun's activity is a great way to create a connection with our nearest star. Over the course of a few days, you'll start to reveal the dynamic, changing nature of its 'surface' features and understand how these features appear to rotate across the Sun's disc.

Step 4

Fit the card ring from Step 2 to the telescope and apply four pieces of double-sided tape to it. Pointing the scope skywards, carefully place the film over the card ring and press it down so it sticks. Use regular tape to secure the film to the card ring so there are no gaps.

Step 5

Cut out another set of 50mm-wide strips of card and join them end to end as in Step 1. Attach double-sided tape to this card and wrap it around the first card ring and solar film assembly from Step 4. Tape down the end of the card strip to finish the filter off.

Step 6

Hold the filter up to the Sun to check for holes. Discard and remake if you find any. If it's good, point the scope away from the Sun, fit the filter and remove/cap any finderscopes. Aim the scope at the Sun using its shadow as a guide – then you can insert an eyepiece.

Make a solar funnel

By Mark Parrish

This easy-to-make device fits directly to your scope for a spot of safe solar viewing

▲ Long summer evenings and a solar funnel make an ideal combination for viewing the Sun

Summer months are a great time to indulge in a bit of solar observing. But you can't simply point your telescope at the Sun – without an appropriate filter or a projecting device attached, you'll almost certainly lose your eyesight. With this solar funnel, though, you'll have an effective accessory to use with your refractor for some safe Sun spotting – as well as a way to share your observations with friends.

WARNING
Do not look directly at the Sun with the naked eye or any unfiltered optical instruments

The solar funnel is simply a hollow cone with an eyepiece fitted in the narrow end and a translucent screen at the other. It uses a projection technique to disperse sunlight over a wide area and onto the screen. Because the eyepiece is internal, there is no way for anyone to accidentally look into the light path. Although this is a safe technique, it is still important that your equipment is never left unattended, especially when children are around.

The length of the cone is calculated to suit small refracting telescopes with a focal length between 300mm and 1,000mm. Because the aperture of such telescopes will be relatively small and they lack internal structures, heat build-up is not a problem. However, if your scope's main lens is larger than 3 inches we recommend reducing the effective aperture by using a cardboard mask with a smaller hole (2 inches) cut in the centre and taped over the dew shield. Solar funnels are less suitable for use with Newtonian reflectors as these telescopes have large apertures and the secondary mirror can be damaged by heat.

Funnelling the Sun

The solar funnel displays the Sun in white light – in other words, all the visible wavelengths of light are seen. The eyepiece determines the size of the image; we found that any eyepiece with a focal length between 12mm and 25mm produces acceptable results, so you may be lucky enough to have a suitable candidate in your accessory box already.

Using a solar funnel is straightforward. After capping your main lens and any accessories – such as finderscopes – and with your eyepiece fitted, position it in the focuser. Ensure the eyepiece is firmly fixed in the funnel and gripped in the focuser. Next, align the telescope with the Sun – the easiest way is to watch the shadow the telescope tube casts on the ground. Line up the scope so the shadow becomes small and round. When it is, you should be pointing towards the Sun. Remove the lens cap (or uncover the opening of your aperture reducer, if you fitted one) and you should see a bright image of our star somewhere on your screen.

Finally, make small adjustments to the mount and focuser to centralise the image and bring out any fine details on the Sun's

TOOLS AND MATERIALS

Cardboard and tracing paper
Three pieces of thin, A4 packaging card for the funnel. Tracing paper works really well for the screen, although any translucent, thin material is worth trying.

Eyepiece
Any low-cost eyepiece with a focal length in the 15–25mm range will suffice.

Finish
A non-reflecting, matte black spray paint works well as an internal finish. For the outside, you could use gloss paint or sticky-backed plastic.

Tools and sundries
Craft knife, steel ruler, hot-melt glue gun or strong craft glue, spray adhesive or glue stick, black duct tape or electrical tape, strong elastic bands.

ALL PICTURES: MARK PARRISH

▲ A solar funnel can reveal sunspot groups – one is visible at the top right of the solar disc here

"A solar funnel is simply a hollow cone with an eyepiece fitted in the narrow end and a translucent screen at the other"

surface. All being well, you should be treated to a display of sunspots, which appear dark against the bright surface.

You could sketch these and keep a record or (as we did) photograph the screen using a camera or smartphone. If you're feeling ambitious you could draw a circle on your tracing paper screen in advance and then mark sunspot positions in-situ with a felt-tipped pen. Replace this screen after each viewing session and keep them as a record of your observations. You should also be able to see variations in tone across the solar surface.

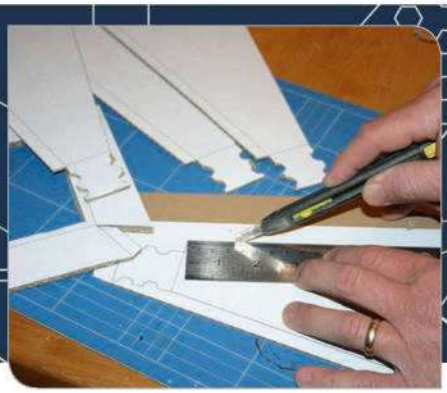
A nice paint finish or sticky-backed plastic covering would increase the solar funnel's longevity; the logo is, of course, optional. Whatever you choose to do, we know you'll get a lot of pleasure from making and using this simple device.

MORE ONLINE
Print templates to make your funnel

STEP-BY-STEP

Step 1

Start by printing out two copies of the funnel template and one copy of the back screen panel. You can find them in the bonus content on our website at www.skyatnightmagazine.com/bonuscontent. Stick the templates to A4 card using spray adhesive or a glue stick.



Step 2

Using a steel ruler to keep the lines straight, carefully cut out the four sides of the funnel and the back screen panel. Score or partly cut the dotted lines where the card will be folded. The templates can be gently peeled off or left in place.

Step 3

Use a hot-melt glue gun (or strong glue) to bond the four sides of the funnel together and make up the back screen frame. Use tape to temporarily hold the parts together if you're using traditional glue. Don't glue the four 'jaws' at the bottom of the funnel together.

Step 4

Before fixing the tracing paper, give the inside of the funnel and the whole back screen frame a generous coat of matte black spray paint. You could also cover the joints using black tape to keep out stray light and neaten things up.

Step 5

Cut a square of tracing paper and tape or glue it across the inside of the opening of the back screen frame. Glue the back panel into the end of the funnel to attach it permanently or tape it if you think you'll want to change the screen occasionally.

Step 6

Remove your eyepiece's rubber eye-shield and push it between the four 'jaws' at the bottom of the funnel. Wrap strong elastic bands around the 'jaws' to hold the eyepiece in place. Apply additional tape to hold it securely.

BIG BUILD

You can safely observe sunspots by projecting an image of the Sun

WARNING
Do not look directly at the Sun with the naked eye or any unfiltered optical instruments

Make a SOLAR PROJECTION SCREEN

By Mark Parrish

Record features moving across the face of the Sun with this simple device

Summer heralds the start of longer days and shorter nights. It's an ideal time to take a close look at our nearest star: the Sun. You should never make direct observations of the Sun with the naked eye or a telescope. The intense heat can damage your eyesight and equipment. The solar projection technique described here can be traced back to Galileo and, providing care is taken when setting up and supervising the equipment, it is a safe and effective way to enjoy the Sun's surprising and varied features.

The Sun is a seething ball of nuclear reactions, magnetic fields and hot gases, but when you view the surface in normal white light – as you do with a projection screen – you see just the bright surface of the Sun's photosphere.

The solar projection screen is a flat, lightweight panel supported by two thin rods about 500mm beyond the eyepiece of a refractor telescope. Light from the Sun is focused by the telescope and eyepiece onto the screen, forming an image about 150mm (6 inches) across. When you project the solar disc onto the screen you may be lucky enough to see some evidence of the turmoil within. Sunspots, for instance, slowly traverse across the central regions. They're cooler than the surrounding photosphere, making them appear darker. Another feature you may see is faculae. These bright regions of incandescent gas sometimes precede the formation of sunspots.

Heat shield

Projecting the Sun through your telescope can create a lot of heat. To keep the telescope's temperature down you first need to make an aperture reducer, which reduces the amount of light coming into the telescope tube. Some telescopes are provided with a dust cap with a small opening for this very purpose, but you can make one from cardboard with a hole of about 45mm in diameter cut from the centre. Simply tape this to the dew shield.

The Sun's image should be projected onto a recording sheet (you can print one off at www.skyatnightmagazine.com/bonuscontent). Clip it to the projection screen with paperclips or pegs so you can trace any sunspots or interesting features with a pencil. There is also space on the sheet to record information such as the date, time and atmospheric conditions.

The projection screen has two tubes or 'sliders' glued into it, allowing it to slide along the rods and 'zoom' in and out to ▸

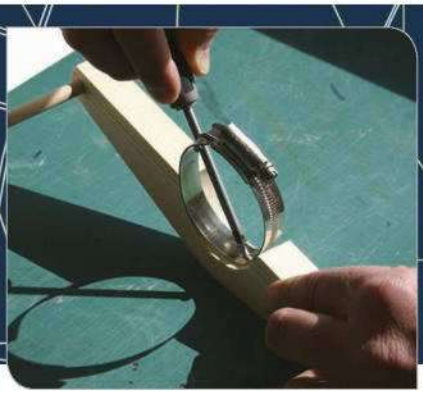
STEP-BY-STEP

Step 1

Print off the templates from our website and stick those for the projection screen and the Sun shade to stiff cardboard. Carefully cut round them with a craft knife. Stick the support arm template to the piece of softwood.

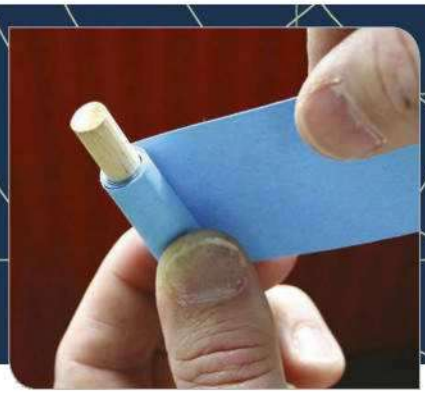
Step 2

Select a suitable semicircle on the template that suits your drawtube. Cut the shape out with a coping saw or jigsaw and cut the tapering ends to reduce the weight of the arm. Drill holes through the markings so the dowels will fit tightly in each end.



Step 3

Fit the jubilee clip into the semicircular cutout by first drilling a small hole about half way along the steel band and then screwing through into the wood. A generous squirt of glue or a second screw will prevent any twisting later on.



Step 4

Roll strips of thin card or paper around the dowels and tape them up to make two sliders. Punch or cut holes in the projection screen and glue the paper rolls into them. These allow you to slide the screen up and down the dowels to change the image size.

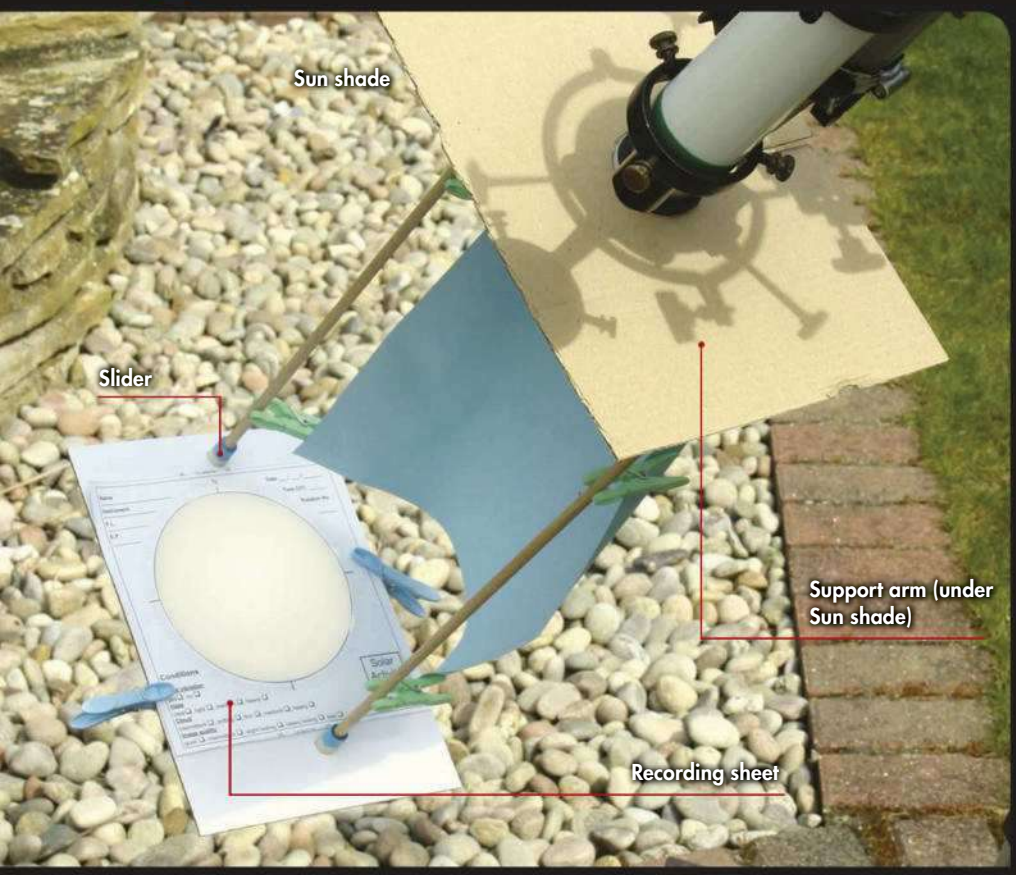
Step 5

Glue the dowels into the support arm and slide on the projection screen. Wrap a strip of foam or tape some fabric around the drawtube to prevent any scratching. Fit the unit onto the scope and tighten the jubilee clip onto the foam padding.

Step 6

Make a cardboard aperture reducer with a 45mm hole. Clip a recording sheet onto the projection screen. Line up the scope, remove the cap, focus and start observing. Clip a curved sheet of paper to the dowels to create more shade if required.

MARK PARRISH X 7, ISTOCK



◂ The solar projector is easy to make and enables you to record solar features with a pencil

▸ create the required size of image that you see on the recording sheet. The rods are glued firmly at the telescope end into the wooden support arm, which provides a rigid support for the whole unit. The arm is shaped to fit around the drawtube of your telescope and is also tapered towards the ends to help reduce the weight.

The entire unit is joined to the telescope with a jubilee clip. These adjustable metal bands are usually used to tighten around hoses and rubber pipes and can be bought from hardware and car accessory shops. Choose one that will expand to fit around your telescope's drawtube. This is the part that holds the eyepiece and it moves in and out when you adjust your focuser.

Assembly time

The trickiest part of the build is drilling two small holes in the jubilee clip so it can be screwed to the support arm; a good way to keep the clip still when you are drilling is to tighten it up onto a round wooden stick first, to anchor it down.

To prevent the metal jubilee clip causing any scratches on the drawtube when you fit it, it's a good idea to wrap some electrical tape or thin foam padding round the part where the clip will attach. We found that it was possible to adjust the clip so that we could simply push the unit on and off the telescope when we wanted to use it.

Using your finished device is very straightforward. Look for a good location in your garden or a local park, ideally with a good view of the southern sky, but also sheltered from the wind because the screen acts a bit like a sail and can cause unwelcome vibrations. Mount the scope on a normal tripod – you'll need to extend the legs fully to accommodate the projection screen. If there are children around make sure you don't leave the telescope unattended.

Fit your aperture reducer to the front lens of your scope and cover the opening while you aim the telescope towards the Sun. Point the scope towards the Sun as accurately as you can by making the shadow cast by the telescope onto the Sun shade as small as possible. Switch on the motor drive if you have one and remove the lens cover. Make fine adjustments so that the Sun's image falls centrally on the recording sheet.

Focus the image using your scope's focuser and move the screen back and forth along the dowels until the image fills the 6-inch circle on the recording sheet. If you can see any sunspots or faculae, use a soft pencil to record their position. If you repeat this procedure over a number of days, you can track the progress and development of sunspots as they rotate around the photosphere – a fascinating and scientifically valuable activity.

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

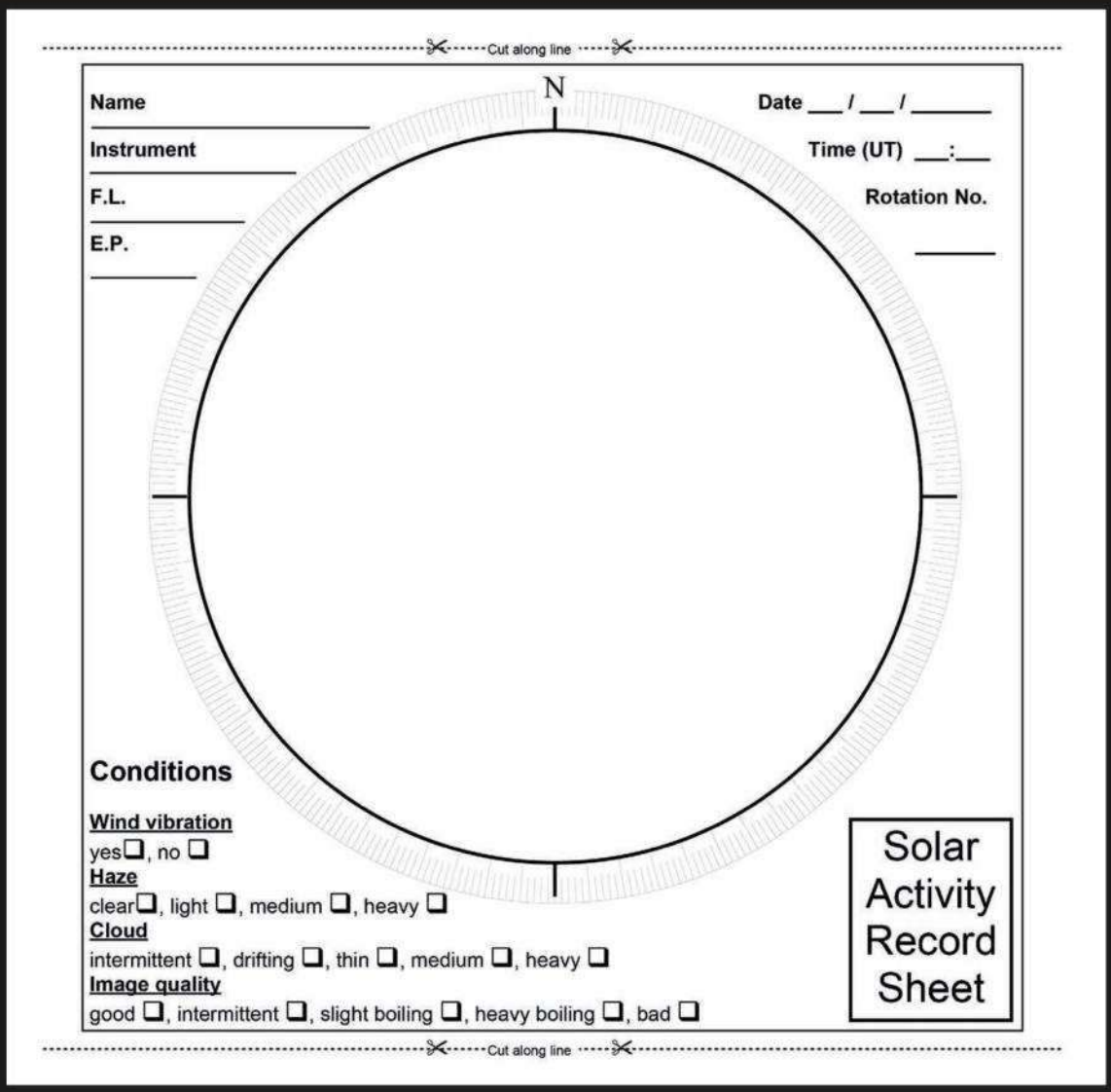
Cardboard
Use an A4 sheet of corrugated cardboard for the projection screen, and a similar sized or larger piece for the Sun shade.

Eyepiece
A low-power eyepiece with a focal length of about 15–20mm works well. Cheap ones are fine, but avoid those with plastic parts or cemented lenses as they can get hot when aimed at the Sun.

Refracting telescope and mount
A small aperture refractor with a medium to long focal length works best. A 60–80mm aperture is fine. This method doesn't work with a reflector or catadioptric telescope. Whatever the size of your telescope, make a mask from card for the objective lens to reduce its aperture to about 45mm; this will lessen the heat involved. Metal focusers and tubes are better than plastic.

Tools
Use a coping saw for shaping the support arm, a hand drill with suitable bits for the screws and dowels, and a craft knife for cutting cardboard. Use tape and glue to join the parts together.

Wood and dowels
For the support arm you need a piece of softwood about 250 x 50 x 18mm. The two dowel rods are about 8mm in diameter and 600mm long. Use a jubilee clip to fix the support arm to the scope; choose one that matches your drawtube size.



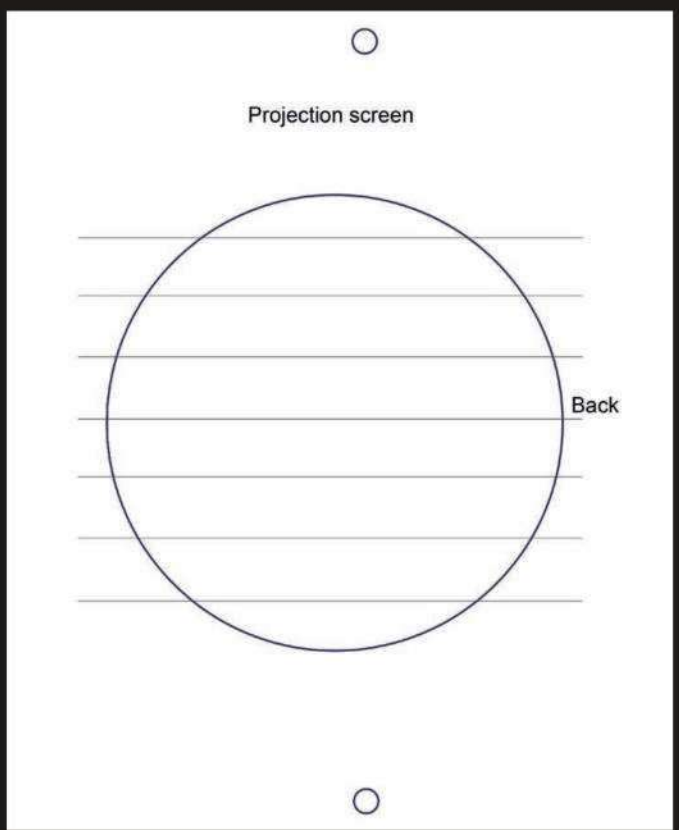
MORE ONLINE

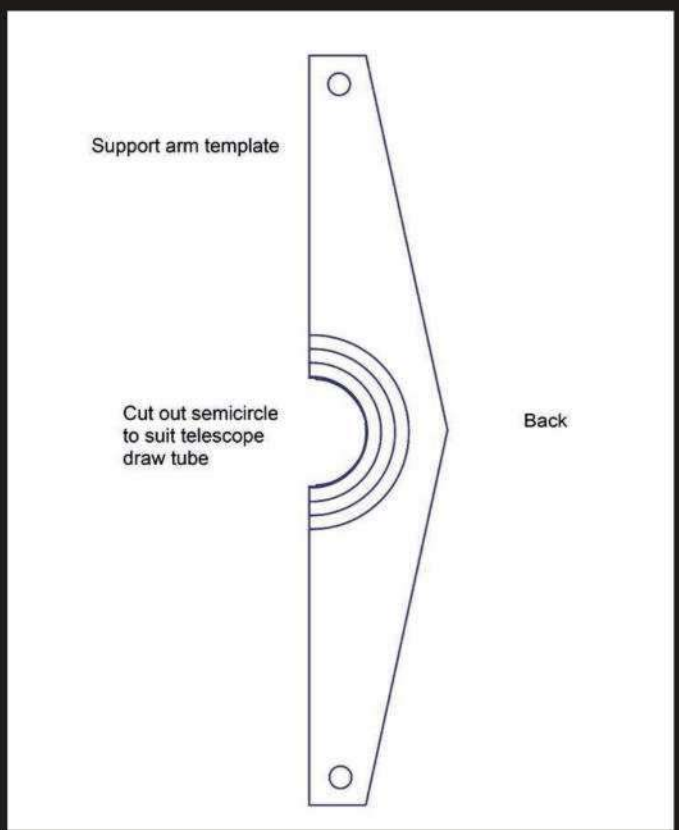
Print these and more design templates and observing forms

◄ Print out templates to record and draw your observations and also log the conditions

▼ Below left: The projection screen template will help you gauge the position of sunspots

Below: Ensure your support arm is accurately cut with this template





Make a simple solar finder

By Stephen Tonkin

Align your scope with the Sun in seconds

The completed finder is a great complement to any white light solar observing setup

ALL PICTURES: STEPHEN TONKIN

Non-solar telescopes fitted with white light filters can be difficult to align to the Sun. One option is to make another white light filter for your finderscope, but it's difficult to securely fit a filter to a reflex (red-dot or projected reticule) finder; those that display a projected reticule can be permanently damaged by being exposed to the unfiltered Sun. So, for this project we're going to show you how to make a permanent solution: a bespoke solar finder.

A word of caution. You must ensure that the full aperture of any instrument you use to observe the Sun is covered with

TOOLS AND MATERIALS

Materials

12cm of 22mm-diameter copper or white plastic plumbing pipe, 22mm stop-end, 22mm brass compression straight coupler, two compression fitting inserts (if using plastic pipe), translucent plastic milk bottle, 6x30mm finder bracket.

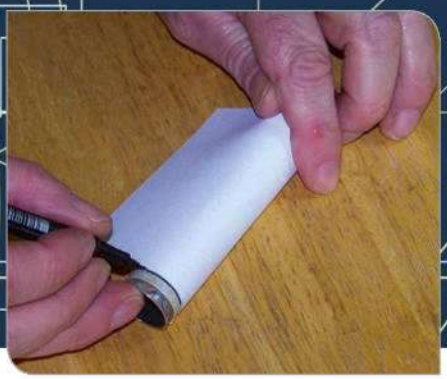
Sundries

Self-amalgamating or electrical tape, safety glasses.

Tools

Awl, drill (5mm), pipe-cutter or hacksaw, masking tape, small half-round file, vice with soft jaws, two adjustable spanners or fixed-jaw spanners to fit 22mm cap nuts (32mm across the flats), scissors, fine-tip permanent marker, craft knife.

STEP-BY-STEP

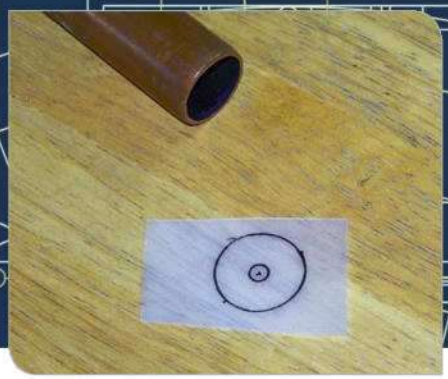


Step 1

Cut two lengths of pipe: one 8.5cm long for the finder body and another 1.5cm long for the retaining ring that holds the screen in place. If you don't have a pipe-cutter, wrap the pipe in paper and masking tape, and mark a 'square-cut' ring.

Step 2

Use an awl or a similar tool to remove the tiny dimple in the recess in the middle of the face of the stop-end. Use the recess as a guide to drill a 5mm hole in the centre of the face. Wear safety glasses when you're drilling.



Step 3

Cut a flat section of plastic from the milk bottle, approximately 25mm square. Use a fine-point permanent marker to draw around the end of the pipe, then draw a reticle inside the resulting circle. Carefully cut out the screen on the inside of the circle line.

a proper solar filter or filter-mask combination, which you should check before each use. If you do not do so, you risk causing instant and permanent damage to your equipment or eyes.

The essential criteria for any solar finder are that it must be easy and safe to use, and that it should be sufficiently robust so it can't be easily damaged. The safety criterion means that there must be no way that you can inadvertently use it to look directly at the Sun. You'll find it easy to use if its bracket simply replaces that of the conventional or reflex finder in the telescope's finder shoe. For this reason, we've used a Sky-Watcher finder bracket, which will also fit the finder shoe of several other brands of telescope.

This solar finder is essentially a short pinhole camera with a recessed screen – the fact that it's recessed means that it can't be easily damaged. The screen is secured in place by the retaining ring in a brass compression fitting so it can't inadvertently fall out, even with vigorous shaking. Additionally, the finder can't be removed from the bracket without using tools as the release collar of the stop-end fitting at the front of the finder is inaccessible, so there's no possibility of it being accidentally dismantled.

We've chosen components that are easily available, require minimal adaptation and are easy to assemble. They easily meet the robustness criterion in that they're tried and tested for a purpose that's significantly more demanding than use in a solar finder.

▲ After you've centred the Sun once, the finder should remain perfectly aligned

The stop-end we're using is the SpeedFit; it's a very near fit to the front end of a Sky-Watcher 6x30 finder bracket, with three or four turns of electrical tape to secure it. The circular collar on the cap-nut of the brass compression fitting is an ideal diameter for the bracket's adjustment screws.

Bring it into line

Resourceful readers can freely adapt the design so that it will fit a different bracket or can be made from alternative materials that are already to hand. For example, our prototype used the lid of a 35mm film canister and the eye cup from a broken pair of binoculars, both of which serendipitously fitted a piece of focuser drawtube from our junk box. We had to modify the base of the finder bracket with a hacksaw and file in order for it to fit the finder shoe on the telescope.

WARNING
Do not look directly at the Sun with the naked eye or any unfiltered optical instruments

The first time you use your solar finder, you'll need to align it to the main telescope. Attach the finder and fix the telescope's solar filter in place. Using a low-magnification eyepiece, centre the image of the Sun in the main telescope. Adjust the finder bracket's alignment screws so that the projected image of the Sun is central on the finder screen and check the main telescope again. It usually takes two or three goes before the finder is properly aligned, after which it remains permanently lined up unless you adjust the alignment screws in the bracket.

From then on, all you need to do is fix the telescope's solar filter in place, attach the solar finder to the telescope, and move the telescope so that the projected image of the Sun falls onto the centre of the reticle on the finder's screen. Finding and centring the Sun now takes only a matter of seconds. This ease and speed of acquiring the target is especially valuable when you are trying to observe the Sun through gaps in the cloud on overcast days.

Step 4

Insert the screen, ink-side first, down to the stop-end in one side of the compression coupler. Slip the compression fitting over the 1.5cm retaining ring and put it in place. Screw on the cap-nut and use the long pipe to push the retaining ring fully home.

Step 5

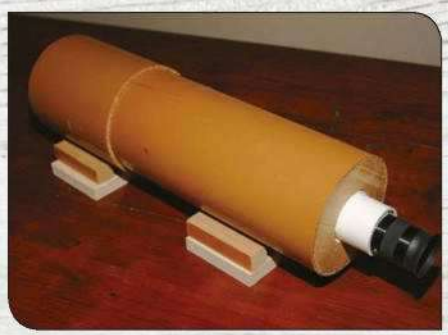
Put the collar of the open end of the stop-end into the finder bracket and judge how many layers of electrical tape you will need to make it fit snugly. Wrap the tape onto the collar and trim it so that it won't interfere with the release collar.

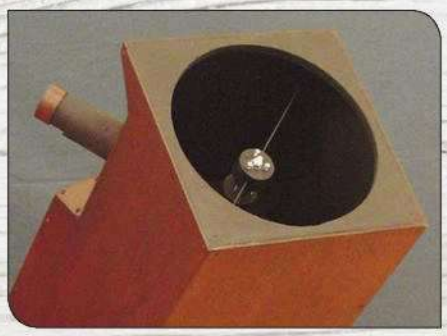
Step 6

Put the long length of pipe into the compression fitting and tighten both cap-nuts half a turn. Attach the finder to the bracket, ensuring that the alignment screws bear onto the circular cap-nut collar. Push on the stop-end to secure the finder firmly in place.

TELESCOPES

If you already own a telescope, here you'll find projects that will upgrade it. Also in this section are full plans and instructions to make your own Dobsonian telescope, including how to grind your own mirror





BACKGROUND IMAGE: ISTOCK, TERRY PEARCE/SIMON LANG, SIMON LANG, MARK PARRISH

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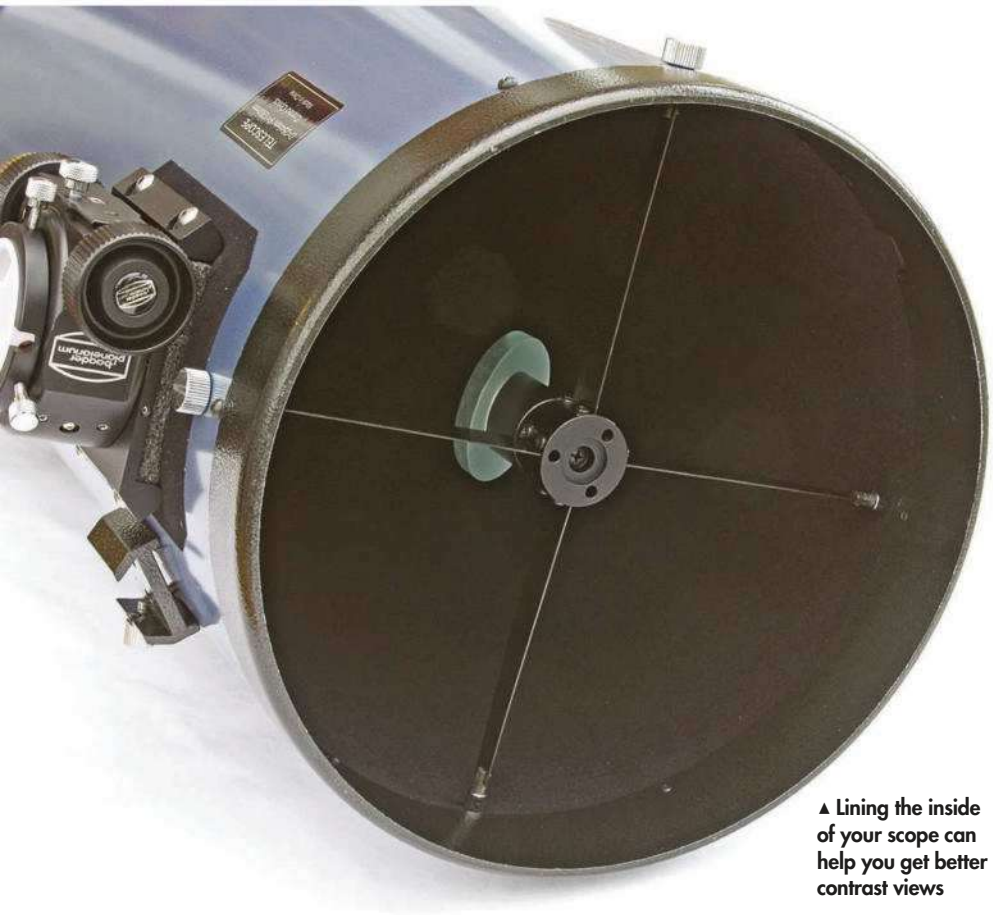


▲ Lining the inside of your scope can help you get better contrast views

Flock a Newtonian telescope

By Steve Richards

Block out unwanted reflections with this straightforward project

One of the problems associated with Newtonian reflectors is the reduced contrast of the view in comparison with a refractor. There are various causes of this, including the central obstruction created by the secondary mirror. While there's not much you can do about that, another contrast-zapping issue – the reflection of stray light – can be tackled head on. That's where this DIY solution comes in.

The open-ended design and relatively large apertures associated with Newtonian reflectors make them a magnet for stray light entering the optical tube, where it can be reflected into the eyepiece. The result is wishy-washy backgrounds and reduced contrast. Adding a long dew shield to the front of the telescope to prevent stray light from reaching the inside of the tube can lead to an improvement, but there are other areas where reflections can be a nuisance.

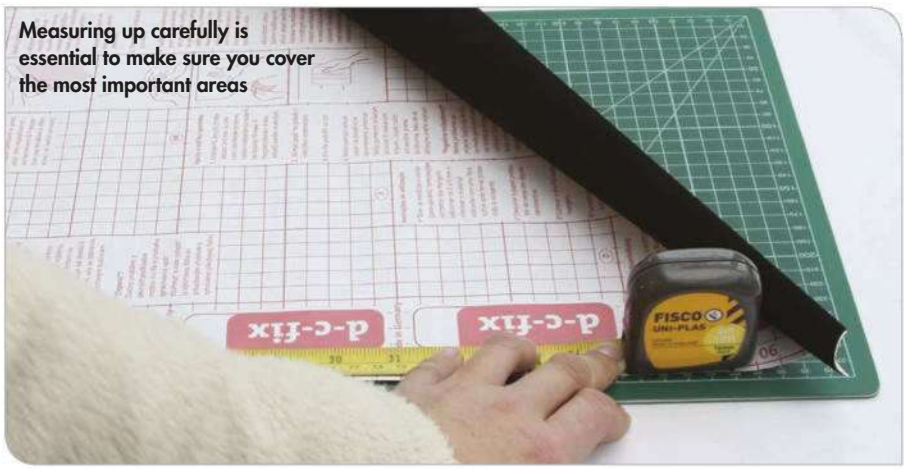
All manufacturers make some attempt at removing stray reflections by painting the inside of the tube with matte black paint. Although this is helpful, it doesn't always resolve the issue effectively, as even matte black paint is reflective to some extent and the quality of the paint's application can be variable. High-end instruments are designed with baffles placed at strategic intervals down the inside of the tube to absorb unwanted light and these can be very effective indeed, but are probably beyond the DIY skills of most amateur astronomers.

Fight the light

Lining the inside of the telescope tube with black flocking material, on the other hand, is a simple and very effective way of killing unwanted reflections, as the light is simply absorbed by the relatively 'rough' and very black surface.

To give an idea of the main areas that should be covered with the flocking material as an absolute minimum, first remove the eyepiece and tube dust cover and look through the focus tube. Every surface that you can see (with the exception of the mirrors!) should be covered with flocking material as they are all likely sources of unwanted light. In reality, it makes most sense to cover as much of the inside of the tube as possible. The black velour flocking material we used is available in 45 x 100cm sheets bought in roll form; take care to choose packs that have not been dented. You'll need to calculate the amount of flocking material required for your own particular scope. For this purpose, you should assume that you will be flocking the whole of the inside of your optical tube.

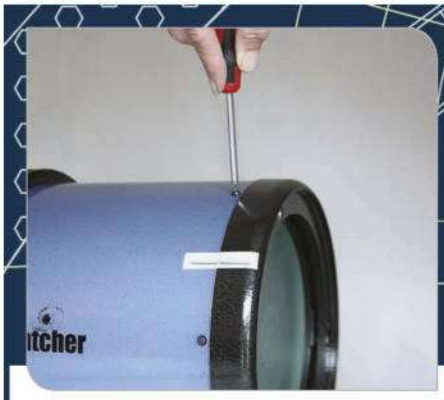
The total amount of material required can be ascertained by determining the circumference of the tube then measuring the tube length. The tube circumference is simply found by multiplying your telescope's physical aperture (the diameter of its tube) by π. For example, our 10-inch Newtonian reflector has an actual tube diameter of 28.8cm, so the circumference will be 28.8 × 3.14, which equals 90.5cm; the length of the tube is 107.0cm.



Measuring up carefully is essential to make sure you cover the most important areas

ALL PICTURES: STEVE RICHARDS

STEP-BY-STEP



Step 1

Start by disassembling the telescope. Place pieces of masking tape on the tube and baseplate so that you can return them to the same position later. Loosen the small screws that retain the base of the telescope and remove the whole of the primary mirror cell.

Step 2

Gently hold the secondary mirror assembly through the spider vanes. Remove the central retaining screw from the vanes and withdraw the mirror. The spider vanes can then be taken out using the knurled knobs that normally hold them to the edge of the optical tube.

Step 3

Leaving the front ring that supports the spider vane in place to give the tube some stability, remove the focuser assembly – using either a crosshead screwdriver or Allen key as appropriate and a small spanner to hold the nuts still. Now remove the finderscope base.

Step 4

Cut the first length of flocking material, allowing a 5mm overlap for the internal circumference. Starting at the front, peel off about 10cm of the backing sheet and gently apply the flocking material to the inside of the tube, smoothing it out and unrolling it as you go.

Step 5

Apply the rest of the material from the bottom end, butting up to the edge of the first piece if you have enough. Using the craft knife, carefully cut out holes for the focus tube and mounting bolts. Re-install the finderscope bracket and focuser assembly.

Step 6

Assemble the rest of the components in reverse order, being very careful not to touch any of the mirror surfaces and ensuring that the masking tape markers line up accurately. Finally, carry out a full collimation of the telescope using a Cheshire eyepiece.

TOOLS AND MATERIALS

Craft knife and cutting board
A sharp craft knife and cutting board are needed for trimming the flocking material to the correct size.

Flocking material
Black self-adhesive film is available from Hobbycraft or Wilkinsons at a cost of about £7 per roll.

Metal straight edge
A steel rule will make it easy to cut a fine accurate edge.

Screwdrivers
A medium-sized crosshead screwdriver and a spanner will be required to remove the focuser and the primary and secondary mirror cells.

Tape measure and pencil
You will need to accurately measure the flocking material and mark it for cutting.

In this example, we would recommend that you cut the material for the circumference from the 100cm length (allowing for a 5mm overlap). A total of three sheets would be required to completely cover the inside of the tube. Alternatively, you could use just two sheets and leave a small gap of 17cm in the centre of the optical tube – where there will be the minimum risk of reflections – and partially fill this area using the off-cuts from the two main pieces.

This inexpensive and simple procedure will have a marked effect on the quality of your views through the eyepiece and will result in higher contrast images too. If you are feeling brave, you could also paint the edge of the secondary mirror matte black, as this too can contribute to stray light. However, only consider doing this if you are absolutely sure that you can perform the work without getting any paint on the surface of the mirror.

Upgrade your Newtonian's focuser

By Steve Richards

Bolster the visual observing and imaging potential of your Newtonian telescope by replacing its focuser

Drilling into your Newtonian may seem an alarming prospect, but upgrading to a new focuser can drastically improve back focus and eliminate image shift

ALL PICTURES: STEVE RICHARDS

Many modern telescopes are supplied with excellent optics and mounts, yet are often let down by their focusers. They often work well enough with smaller eyepieces, but start to struggle with the additional weight of a 2-inch eyepiece or camera, a filter wheel or other accessories.

A second issue with Newtonian reflectors is that of 'back focus', the amount of inward travel required to reach focus with a camera in place. This can be a severe limitation in a Newtonian scope unless it has been specifically designed for photography. One solution to this problem is to replace the original focuser with a low-profile version, which allows the camera to get closer to the secondary mirror and achieve focus. Luckily there is a burgeoning market for upgraded focusers for a wide range of telescopes.

Some replacement focusers will be direct swaps for the original, but this tends to apply to more recent equipment. Our aged Sky-Watcher 250PX Newtonian reflector was originally supplied with an older style rack and pinion focuser. Because of its stiffness in movement, it didn't suffer from an inability to carry loads, but more than made up for this with its limited back focus and high degree of image shift when racking in and out.

Unfortunately, a good-quality upgrade would not fit the original mounting holes, so we had to carry out the installation the hard way by drilling our own. The result was more than worth it, as the new focuser transformed the telescope both as a visual observing and an imaging instrument.

TOOLS AND MATERIALS

Craft knife and compass cutter
Sharp ones will help in cutting the black foam and Fablon-type material to the correct shape.

Electric drill
Plus a suitable drill bit to make the mounting holes for the new focuser.

Foam and Fablon
Black foam and a Fablon-type material will help block out light from the new focuser's edges and the old mounting holes.

Masking tape
This protects the tube during test fitting and marks the position of the new mounting holes.

Screwdriver
A medium-sized crosshead screwdriver to remove the original focuser and the primary mirror cell.

Collimate first

It's essential that the new focuser sits correctly over the drawtube hole in the side of the tube and is accurately centred over the light cone from the secondary mirror. Start off by making sure that your Newtonian is perfectly collimated with the original focuser in place. If you have an accurately collimated laser, you can use this in the original focuser to note the position of the returned beam on the collimator, and later match this when

test fitting the new focuser. If you don't have a laser collimator, then a collimating cap will also do the job of correctly centring the new focuser.

> "We had to drill our own holes. The result was more than worth it – the new focuser transformed the telescope both as a visual observing and an imaging instrument"

With the telescope lying horizontally on a soft surface, supported by cushions to stop it from rolling, remove the original focuser – being especially careful not to touch the secondary mirror or its spider vane assembly. Cover the whole area around the large exposed hole that the drawtube travels through with masking tape, ensuring a generous overlap. Place the new focuser over the drawtube hole and use either the laser collimator or a collimating cap to align the focuser with the secondary mirror. Using a sharpened soft-leaded pencil, mark the position of the mounting holes on the masking tape.

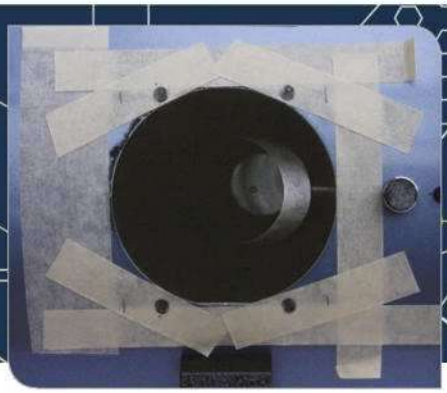
Remove the focuser and disassemble the telescope by first removing the secondary mirror's spider vane assembly from the front. Mark the position of the primary mirror cell section at the rear of the tube using strips of masking tape on both the tube and the unit, and then remove it from the rear of the telescope. You may feel that now would be a good time to clean the mirrors, but they can be easily damaged so only do this if they are really dirty.

Next, drill suitable holes through the pencil marks on the masking tape and test fit the new focuser. If any of the holes need to be eased a little, use a small rat-tail file and adjust them until the bolts pass through comfortably. Clean up the inside of the tube, attach the new focuser and reassemble the telescope. Finally, collimate the instrument.

STEP-BY-STEP

Step 1

Lie the freshly collimated telescope horizontally on a soft surface, supported so that it can't roll. Drape a piece of kitchen towel over the secondary mirror to ensure nothing can fall onto its surface and carefully undo the focuser's retaining bolts.

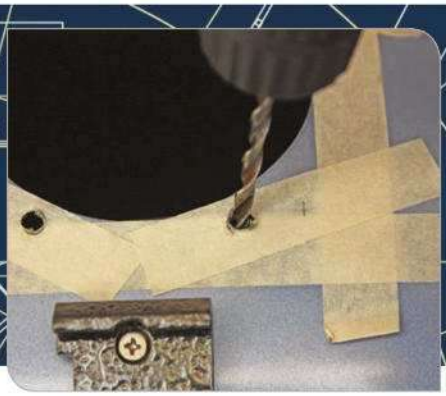


Step 2

Mask the area around the drawtube hole, leaving a generous overlap. Place the new focuser over the hole and use either a laser collimator or a collimating cap to align it with the secondary mirror and mark the position of the mounting holes.

Step 3

Disassemble the telescope by first removing the secondary mirror's spider mounting from the front of the telescope. You may find a supporting plate for the finderscope inside; leave this in position for now. Remove the primary mirror cell from the rear.



Step 4

Gently drill mounting holes in the marked positions using a drill bit 0.5mm larger than the new retaining bolts. Take your time to avoid distorting the tube. If the drill hits the finderscope plate, remove this and drill it separately.

Step 5

Some of the popular focusers are a universal fit, so you may need to take steps to exclude extraneous light from the side of the focuser base. Cut a hole slightly larger than the drawtube in a piece of black packing foam for this purpose.

Step 6

You may need to cover the original mounting holes using a small piece of black Fablon-type material with a hole for the drawtube to pass though. Remove any filings from the inside of the tube and reassemble the telescope, attaching the new focuser first.

BIG BUILD

Make a DOBSONIAN TELESCOPE Part 1

Begin this three-part project by putting together a suitable construction surface: a solid workbench

By Simon Lang

The finished Dobsonian looks good enough to grace a living room

ALL PICTURES: SIMON LANG

Have you ever felt like following in John Dobson's footsteps and building your own telescope? If so, then this is the project for you. Over the next few pages we'll show you how to make an 8.5-inch (215mm) Newtonian telescope and a Dobsonian mount for it – the same type made famous by John Dobson and his band of Sidewalk Astronomers in San Francisco. Dobson's aim was to create a compact and portable scope that's easy to make and use – and that's exactly what we'll be doing here.

So why build a Dobsonian telescope when you can buy one for less than the price of the materials needed for this project (approximately £500)? The answer is the immense satisfaction you'll get from owning a scope you've built with your own hands and viewing the stars through it. The mirror is the main cost when it comes to building a scope, unless you grind it yourself (see p52 for a guide on how to do that).

When assembled, this design weighs about 12kg (26lb) for the optical assembly, plus 7kg (15lb) for the base. And with a vertical height of 140cm (4.5ft) and a 57cm-wide (2ft) base, it isn't too unwieldy either. Best of all, it's made from materials and tools that are straightforward to source.

Its 8.5-inch aperture will enable you to see deep-sky objects in all their splendour and the f/5.5 focal ratio lets you view star clusters with low-magnification eyepieces. With higher magnification eyepieces, the Moon and planets will be large enough to impress.

There are a lot of steps to this project, so we've split it into three parts. This first part covers the construction of a workbench, which you'll need to make if you don't have an old table big enough to rest this large scope on while you put it together. The table's surface needs to be 120 x 80cm – a conventional fold-up workbench would be too small. Making this workbench will give you some carpentry practice before you start on the more critical work of making the telescope. At this stage, it's a good idea to get hold of all the tools and materials that you'll need for the project (see p50).

In the second part we'll detail the optical assembly and its construction, and in the third part we'll explain how to assemble the mount, adjust the optics

TOOLS AND MATERIALS

Turn to page 50 for the full list of tools and materials you'll need

to fit it and align them to collimate the scope. Some basic carpentry and DIY skills are needed for this project, but you can get these by building the workbench with practice. Don't rush either job, as doing so will almost certainly result in a poor final product. Accuracy is the key, especially for the telescope.

Be prepared

It's a good idea to hone your cutting and drilling skills on some scrap materials if you don't work with wood on a regular basis. You can sometimes find useful bits of wood in skips that are suitable of this.

There are plenty of other things to consider before embarking on this project. For example, do you have a first aid kit? Hopefully you won't need it but it's best not to tempt fate. Also, do you have time to see this project through, or will you be left with an unfinished telescope? More importantly, do you have somewhere to build the telescope? Setting up and tidying away takes time. A specific area, such as a garage or shed, that can be left without having to be cleared up every time you use it is useful and will save you a lot of time.

Also bear in mind that your scope will need a home once it's been built. Do you have somewhere to store it? If not, you might want to spend more time on the finish so that it looks good enough to grace your living room.

Materials for this project cost around £250 and a finished mirror cell is about £250, but you can make savings by grinding your own mirror (see p52). The total cost might sound pricey, but you'll end up with a scope that's as good as one you'd buy and which has the bonus of being something you've made yourself.

If you enjoy making this telescope you might even be inspired to design more ambitious instruments – some people have made Dobsonian telescopes with 48-inch mirrors. You don't even have to stick to this particular design. Once you've got an understanding of the basic principles, it's possible to come up with your own designs for a variety of scopes. The reason we picked this particular design, though, is because it's easy for beginners not only to make, but also to use and enjoy.

MORE ONLINE

Find plans and a video to help with Part 1 of this project at www.skyatnightmagazine.com/bonuscontent

TURN THE PAGE FOR PART 2 ▶

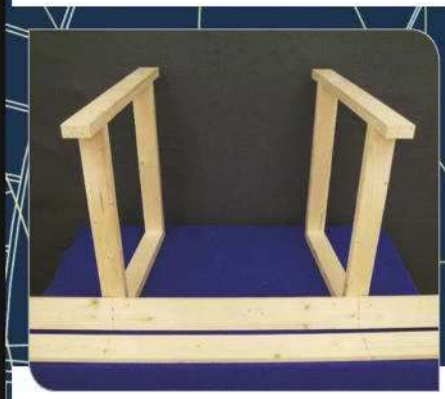
STEP-BY-STEP

Step 1

Check the plans on www.skyatnightmagazine.com/bonuscontent. There's an exploded view and the dimensions needed to cut the timber. Cut the parts to size and label them. Familiarise yourself with how they fit together and their orientation.

Step 2

Start with the thicker support frames. Using a set-square, mark 104mm in from each end of the 700mm-long frame top. Drill two 6mm holes 20mm from each side. Mark the four upright pieces 17mm up from the base and drill two 6mm holes 20mm from the side.



Step 3

Screw the uprights onto the bottom beams with the 6 x 100mm screws. Make sure the frame top is screwed in square by ensuring the uprights are fixed to the top 460mm apart. Mark the 1.2m-long kick plates 250mm in from each end.

Step 4

Drill two 4mm holes through the marks in the kick plates. Screw the plates to the frames with the 4 x 40mm screws. Drill 4mm holes 80mm and 110mm from each end of the 900mm-long top support beams. Fix to the frame tops with the 4 x 50mm screws.

Step 5

Fix the diagonals onto the support frames. Place the upper edge 300mm from the bottom of each upright and mark. Angle it at 20° to the next upright and mark. Attach them with 4 x 40mm screws on the thin sides and 4 x 50mm screws on the wide

Step 6

Centre the frame's plywood top by measuring from the edge of the plywood to the frame underneath. Mark the measurements on top. Then mark the centre of each beam. Drill on this centre line and attach the plywood with 4 x 30mm screws.

BIG BUILD

Make a DOBSONIAN TELESCOPE Part 2

By Simon Lang

It's time to build the Dobsonian's optical tube casing, its mirror cells and focuser

The optics are held in place by a rigid square tube

ALL PICTURES: SIMON LANG

TOOLS AND MATERIALS

Turn to page 50 for the full list of tools and materials you'll need

The tube assembly of a Dobsonian telescope holds the optics and the altitude bearings that enable half of the movement of the telescope. The optical tube casing in this design is made up of a skeleton of four baffles held in place by four struts at their corners. Over this is a skin of four plywood sheets. The holes in the baffles are slightly bigger than the mirror to allow the maximum amount of target light in, but small enough to prevent any stray light entering and interfering with the view. The baffles have 12mm squares cut from each corner to house the struts, which also keep the tube sides square.

The struts provide a surface for the 3mm-thick plywood skin to be attached to, and reinforce the corners. They're fragile, especially in between the baffles where they're not supported. Don't put too much weight on the struts until you've glued on the plywood skin; once the glue has set, the tube will be strong.

At the bottom of the tube is an outer 9mm-thick plywood skin, which acts as a box to house the primary mirror cell and strengthen the tube sides where the bearings support it. Using thicker 9mm plywood at the bottom helps lower the tube's centre of gravity and allows the telescope's bearings to be closer to the ground. Because of this you can build a lighter, but more rigid, cradle mounting (see part three on p48).

A cool mirror

The primary mirror cell is made of two pieces of plywood: a square back plate and a round mirror support. Both pieces have large holes drilled through them to allow air to circulate and cool the mirror; the mirror won't produce its best views until it reaches the same temperature as its surroundings.

The back plate has to be small enough to fit in the square opening at the bottom, while the round mirror support needs to be no wider than the mirror itself. In this design we've allowed for a mirror slightly bigger than 8 inches. The Camden Amateur Telescope-Making Society (bit.ly/2E9CAkD) can supply 8.5-inch (218mm) blanks, but if you intend to find your own, make sure that the mirror support is the same diameter, but no greater than 8.5 inches.

The mirror cell has three bolts running from the circular support plate through

the square back plate. Between the support and back plates are three springs, and by screwing wing nuts on the bolts behind the back plate, the support is 'sprung' away from the back plate. This allows you to collimate the telescope.

The secondary mirror is stuck to a holder that's attached to a 'spider' with a bolt. The spider and mirror holder are made from the plywood discs removed from the primary mirror cell. Two of the 12mm thick discs are glued together to make the spider and two aluminium strips join it to the tube assembly.

The mirror holder is made of four discs glued together with a 45° face cut into one end. The secondary mirror is then stuck onto this face with silicone mastic. A central bolt, with its head loosely housed in a rebate (recess) in the first plywood disc of the holder, passes through the spider's hub and then has a washer and nut screwed on. This nut is used to adjust the holder's vertical position, while three small screws arranged around the main bolt adjust its orientation. These screws pass through the hub to push on a washer on the top of the holder. This triangular arrangement of screws around the central bolt allows movement in all directions.

The focuser is made of a cardboard postal tube and paper. A 450mm postal tube holds a 2-inch eyepiece firmly and two thicknesses of tube are used to make it sturdy. This forms the holder and the 2-inch drawtube that holds the eyepiece. Inside the 2-inch drawtube is a 2- to 1.25-inch adaptor, which is made using loo roll inserts and cardboard from a cereal packet. Lastly, inside the adaptor is a 1.25-inch drawtube made from sections of cardboard and paper. The focuser works by gently twisting either one of the drawtubes, as you push it in or pull it out.

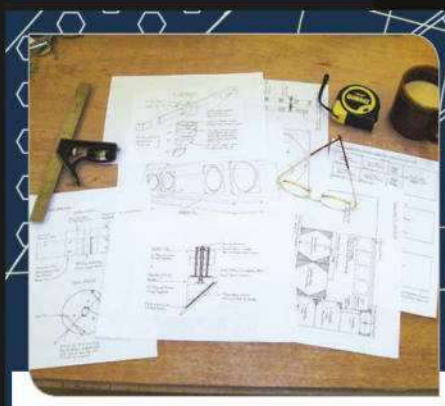
The final job for this part of the project is to make the tube covers; these are just squares of 9mm plywood with 3mm lips stuck to their sides to fit over the ends of the tube. Before you start, check the bonus content at www.skyatnightmagazine.com/bonuscontent where you'll find a short video and extra images of the steps in this part, as well as further instructions, layouts and the diagrams you'll need.

MORE ONLINE

Find plans and a video to help with Part 2 of this project at www.skyatnightmagazine.com/bonuscontent

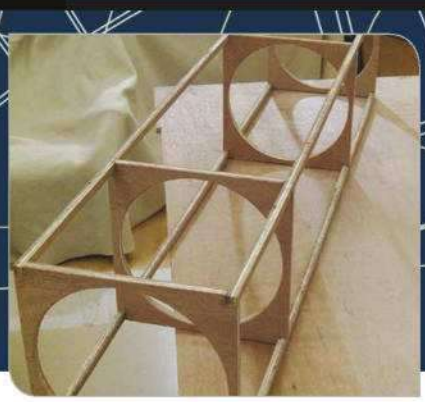
TURN THE PAGE FOR PART 3 ▶

STEP-BY-STEP



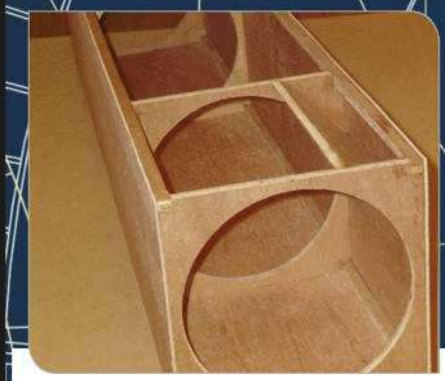
Step 1

Use the plans in the bonus content online to mark your plywood sheets. The pencil marks should be outside the measuring lines and the cut should be outside the pencil marks to just remove them, without cutting into the piece you want to use.



Step 2

Cut out the baffles' centres and 12 x 12mm corner indents with the coping saw. Glue the struts on to the baffles. Use one baffle to support the struts while gluing the other baffles in. Install the focuser's base recess. Use the set-square to make sure it's square.



Step 3

Glue and screw the two narrower 3mm-thick plywood sheets on to the skeleton. Finish any rough edges with the block plane. Apply the first overlapping 3mm sheet and paint the inside of the tube (including the last side) matte black.

Step 4

Glue and screw on the last 3mm-thick side. Attach the 9mm sheets so that they overhang the tube's base by 60mm. Saw the focuser's rebate (recess) with two 45° cuts, then finish them with a utility knife. Glue on two 3mm triangular pieces of wood.

Step 5

Drill the vent holes in the back plate and primary mirror support. Sand both and paint them black. Assemble the mirror cell and spider using cut-offs from the vent holes. Paint the spider and secondary mirror holder black, but don't adjust the screws.

Step 6

Make the four-piece focuser using a postal tube, cardboard and loo roll tubes. Paint the internal surfaces matte black. Drill a 57mm hole for the drawtube in the focuser rebate. Glue on the focuser holder and make the top and bottom tube covers.

BIG BUILD

Make a DOBSONIAN TELESCOPE Part 3

By Simon Lang

Complete the construction of your telescope by making the mount that your tube will sit in

Teflon and laminate bearings will ensure your Dobsonian moves smoothly

ALL PICTURES: SIMON LANG

TOOLS AND MATERIALS

Turn to page 50 for the full list of tools and materials you'll need

The third and final part of this project involves building the mount. As it's really the engine of the scope it has to operate smoothly so that you can track the objects in the night sky easily.

There are two main types of mount, equatorial and altazimuth. Equatorial mounts are designed so that the telescope's right ascension (RA) axis, the one that points to the Pole Star, is parallel to the Earth's axis of rotation. This means that the telescope can follow a star as it moves across the sky just by adjusting the RA axis, either by hand or using a motor drive. These mounts are complicated to make and require machine-engineering skills.

For beginners, it's far easier to make an altazimuth mount. The name comes from 'alt', an abbreviation of altitude or vertical movement, and 'azimuth', which describes horizontal movement. Altazimuth mounts must be moved in both axes to track a star's movement.

Our Dobsonian uses an altazimuth 'cradle' mount in the form of a three-sided box with semi-circular cut-outs on each side. The cut-outs are for the two semi-circular bearings on the sides of the tube to sit in. The bearings are made from two 12mm-thick plywood semicircles (cut from the offcuts of the baffles you made in Part 2), which are glued together. One of the semi-circles acts as a spacer to keep the right distance between the cradle sides and the tube, while the other acts as a bearing.

Friction free

To make the movement of the mount as smooth as possible, the edge of the semi-circular bearings are covered with a kitchen worktop laminate ('Stardust' laminate made by Formica is a good example) and the cut-outs have small pads of PTFE (Teflon) fitted for the laminate to slide on.

The tube assembly rotates in the cradle but needs to be kept from slipping sideways, so both sides of the cradle have lengths of wood that project up past the semi-circular cut-outs. These 'bearing keepers' are withdrawn from the bearings a little in order to fit a double layer of felt, which prevents them interfering with the tube's movement.

The cradle sides are further stiffened with horizontal 'reinforcing fillets'. These

lengths of wood support the bearing keepers, and you can drill holes in them to keep eyepieces handy, as shown in the main image on the left. Your cradle must be square so that the tube is held straight and moves without sticking. Screwing square off-cuts into the bottom inside corners of the box, keeps it square as it's screwed together.

Once assembled, the cradle is then screwed to the base plate, which is fitted on to a ground board. On the underside of the ground board are attached three 1- to 2-inch², 12mm plywood feet with anti-slip rubber 'shoes' glued on them.

Over the feet, three 1-inch² PTFE pads are glued on the top side of the ground board. The cradle will turn with ease on these thanks to the 450mm-diameter disc of laminate glued to the bottom of the cradle base. The next task is to join the ground board to the base plate using a 2-inch, 10mm-thick bolt through the centres of each. This has large washers on to stop the bolt and cradle moving diagonally. Screw a nylon lock nut on to the bolt, because it needs to be loose enough for the cradle to turn without the nut working loose. When tightening it, aim for a point when movement is easy but the cradle isn't rocking.

Once the cradle is assembled, you've got to find the tube's balance point, where you'll attach the bearings. If you don't yet have the primary or secondary mirrors, which will increase the tube's weight, compensate by adding an extra 3.3kg at the primary mirror end and 100g for the secondary mirror at the other, as well as a 2-inch eyepiece. Then pivot the tube to find its centre of balance and mark it with a line. Next, place the tube upright and square in the cradle. You need to raise the tube up until the balance line is visible in the semi-circular bearing cut-outs. Do this by packing plywood offcuts under the tube until the two are level. With the tube upright and aligned, gently screw the bearings in place.

Once you've done all this, take a step back and admire your handiwork. If you've already bought the mirrors, you'll now have a fully working scope. If not, find out you how you can grind your own primary mirror on p52.

MORE ONLINE

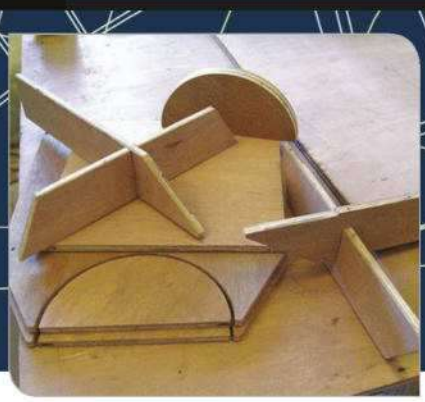
Find plans and a video to help with Part 3 of this project at www.skyatnightmagazine.com/bonuscontent

TURN THE PAGE FOR MORE ▶

STEP-BY-STEP

Step 1

Use the print-out plans in the bonus content to mark and cut out the components. The diagonal cuts on the sides, bearing keepers and reinforcers are all 30° from vertical. Draw the bearing semi-circles onto the cradle sides before cutting them out.



Step 2

Use a 60°/30° set-square to mark out the hexagonal plates. Cut out the notches on the keepers and reinforcers so they fit tightly together. Mark and cut out the keepers' felt rebates. Then file and sand the bearings and semi-circles so they're smooth.

Step 3

Using the 'Making the cradle 3' PDFs as a template, mark out the drill holes in the side panels. Use these holes to drill 2.5mm holes into all the other panels' edges. Then drill 4mm holes in the side panels. Screw the cradle together, making sure it's square.

Step 4

Centre the cradle on the hexagonal plate, mark its outline and drill 2.5mm holes. Turn the cradle over and put the base plate on top. Drill 2.5mm holes into the base. Remove and drill the plate with countersunk 4mm holes. Screw the base onto cradle.

Step 5

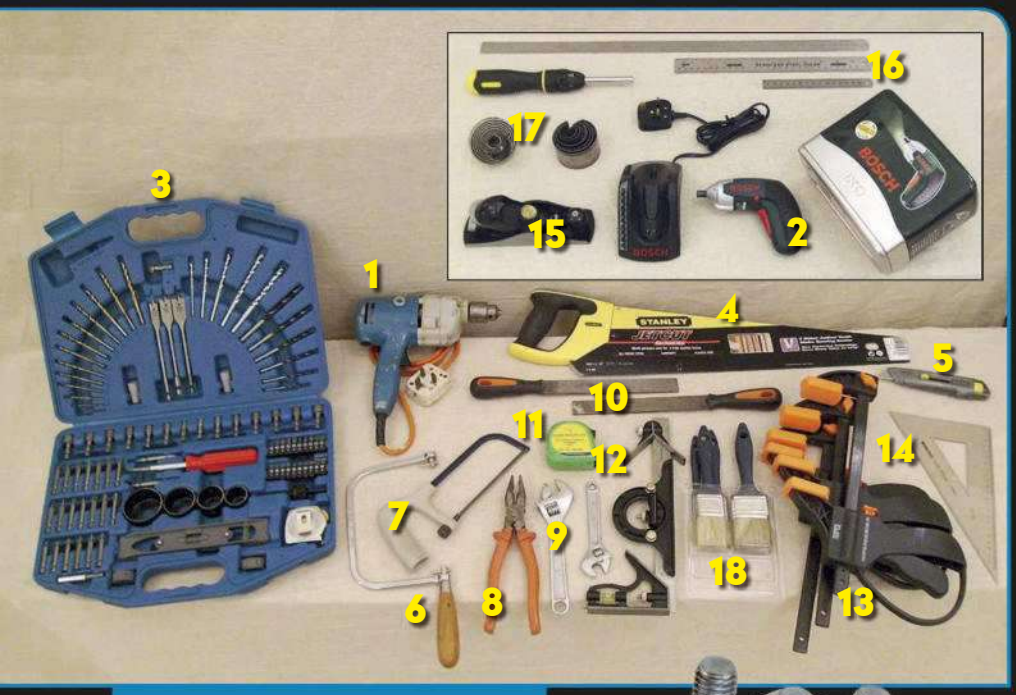
Cut and screw on the ground board's feet. Apply contact adhesive to the laminate, PTFE, felt and rubber pieces and all the surfaces they'll be joined to. When this is tacky, carefully apply them all, rubbing or pushing them down for a good contact.

Step 6

Mark the tube's balance point. Then place the tube upright in the cradle, aligning the balance line with the tops of the semi-circular cut-outs by packing offcuts under the tube until it's at the right height. Screw the semi-circular bearings on to the tube.

Tools and materials

Here you'll find a full list of all the tools, materials and fixings you'll need to make your telescope. As we suggest on the previous pages, it's best to have everything ready before you begin building



Tools

1 500W electric drill
2 Cordless screwdriver
3 Drill bit set, including:
3mm to 10mm HSS/titanium drill bits
A centre-punch
Hexagonal-fit screwdriver bits
4 20-inch handsaw, 11 teeth per inch
5 Utility knife
6 Coping saw and blades
7 Junior hacksaw and blades
8 200mm-handle combination pliers
9 Three-piece wrench set
10 Two-piece rasp and file set
11 5m tape measure
12 Combination measuring set
13 Three clamps
14 Set-square with 30° and 60° corners
15 Block plane
16 Metal rulers
17 Hole saw set
18 Paintbrushes

Fixings

Nuts, bolts and washers
Three M3 50mm slotted pan-head bolts
Four M6 65mm cup square carriage bolts
Seven M6 washers
Four M6 nuts
Three M6 wing-nuts
Seven M6 1.25-inch washers
One M10 2-inch bolt
Four M10 2-inch washers
One M10 nylon lock-nut

Screws
200 3 x 12mm
Two 3 x 16mm
Six 3.5 x 20mm
34 of 4 x 30mm
16 of 4 x 40mm
16 of 4 x 50mm
16 of 6 x 100mm
Screwfix's Goldscrew Pack has all these and more with the exception of the 6 x 100mm (www.screwfix.com)

Materials

Good quality plywood
Two sheets of 3-4mm thickness, 180 x 60cm (6 x 2ft)
One sheet of 9mm thickness, 180 x 60cm (6 x 2ft)
One sheet of 12mm thickness, 240 x 122cm (8 x 4ft)

Lengths of planed pine
Four 1.2m lengths of pine, 69 x 34mm (2.75 x 1.5 inches)
Three 1.8m lengths of pine, 44 x 18mm (1.75 x 0.75 inches)
Two 1.2m lengths of pine, 94 x 18mm (3.75 x 0.75 inches)

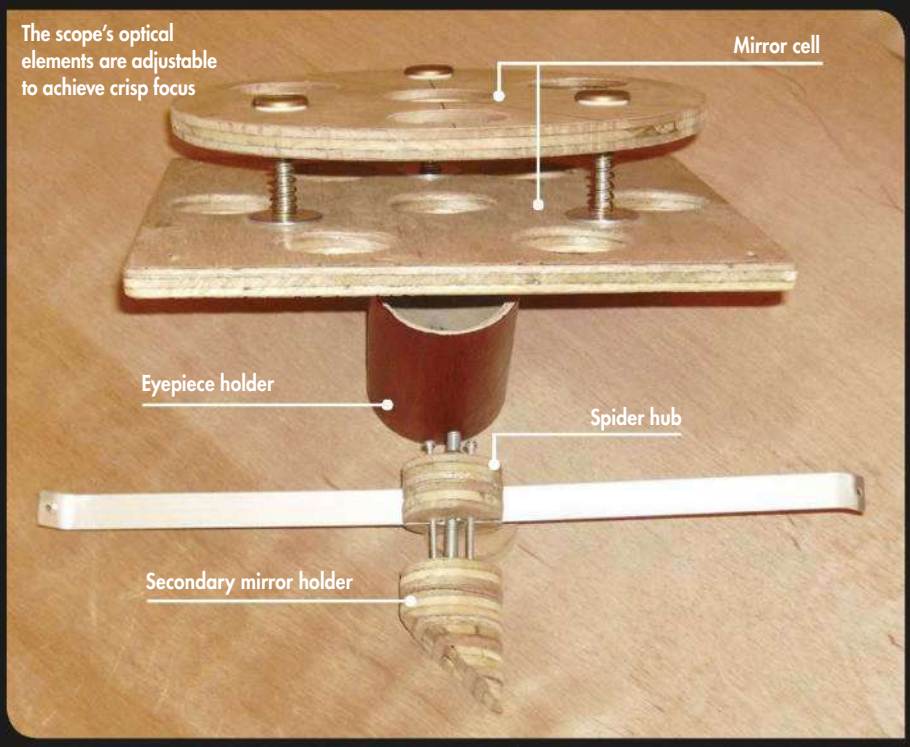
Good wood advice
Sizes can vary from merchant to merchant; as long as you get a close match to the above all will be well. Many merchants deliver for free or have reasonable charges for orders above a certain price, so do ask. If you do place an order, get all the big cuts done in one go to save irritating your supplier. If you look after them, you might find they are a lot more helpful to you. Do not cut any plywood until you have consulted the plans in the bonus content online, or you might have to buy more.

Finishing materials
250ml of wood adhesive
250ml of contact adhesive
1m of 2 x 15mm aluminium strip
Aluminium oxide sandpaper, 80 and 120 grit
1 litre of matte black paint
Woodstain, varnish or gloss paint for final decoration

SIMON LANG X 7, ISTOCK

◄ The Dobsonian's vertical height is 140cm, its base measuring 57cm across

► The scope's optical tube is a simple design; note the black painted interior



▲ A coat of paint hides the focuser's simple cardboard construction

MORE ONLINE

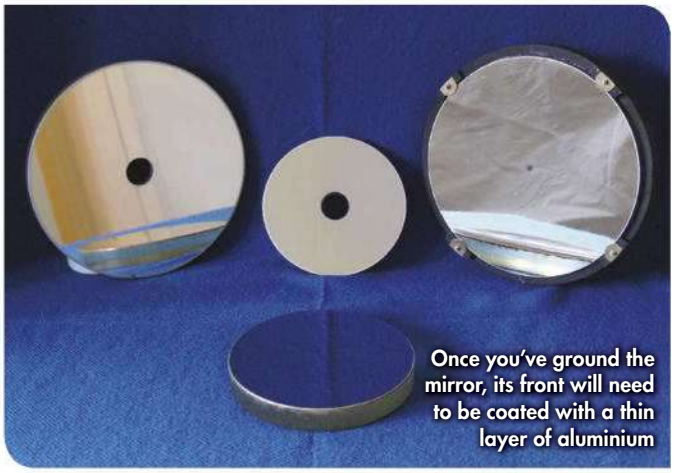
Find plans for this project at www.skyatnightmagazine.com/bonuscontent

Make a telescope mirror

By Terry Pearce and Simon Lang

Collect the Universe's light with a mirror you've ground yourself

The key part of any reflector is its mirror. It needs to be carefully shaped so it focuses the light from the stars onto the angled secondary mirror, which then bounces the light into your eyepiece. It's possible to grind your own mirror but before you start, you'll need to get hold of a mirror blank. The Camden Amateur Telescope Making Society (bit.ly/2E9CAkD) can help here.



Once you've ground the mirror, its front will need to be coated with a thin layer of aluminium

ALL PICTURES: TERRY PEARCE/SIMON LANG

There are several stages to the grinding and it can be a long process. If all goes well, the total work time will be around 24 hours. Before you start grinding, you need to decide on how deeply your mirror blank needs to be ground. It needs to have a focal length equal to that of your telescope. Measure the radius of your mirror and square it. Then multiply the focal length of the mirror by four. Divide the first number by the second and the resulting fraction is the depth you should be aiming for at the very middle of the mirror, the point known as the 'sagitta'.

Once you know this you can begin rough grinding. It's a noisy process and the coarse grinding powder you use is destructive. Keep it away from delicate surfaces and stainless steel sinks, which it can damage. And don't wash the sludge down the sink; put it in the bin. You'll need rough grinding tools, one about 3 inches wide and another about 4 inches wide. They can be any piece of metal – the back of a small axe, a small dumb bell weight, or the head of a hammer. It doesn't even matter if it has flat sides.

Before you begin grinding, choose the best, most flawless side of the mirror blank to work on and place it face-up on a suitable workspace. Place a few layers of dampened newspaper over the surface and have two bowls of water handy, one to wash the mirror and another to mix with the grinding powder. Now sprinkle some of the 80-grade grit and water in the middle of the blank. Use your smallest grinder to grind the central third of the blank using short strokes. When the grinding noise stops the powder is depleted, so add some more.

Focus your efforts

Continue until the curve spreads, then switch to the medium grinder to extend the curve to the edge. Once the curve is correct, start using finer 120-grade powder to smooth out the surface. Check how the curve is shaping up with a Sun test to see if reflected sunlight comes to focus at the correct focal length.

Next comes the smoothing and fine-grinding stage, for which you'll need to make a full-size grinder. Wrap a ring of cardboard around the mirror blank, cover the curved surface with clingfilm and pour cement mortar into the ring. Wait for the cement to set, then separate it from the mirror blank. Stick small ceramic tiles on the resulting curved surface to complete the mirror grinder.

STEP-BY-STEP

Step 1

For rough grinding, use coarse 80- and 120-grade carborundum powder and the small and medium rough grinding tools. Grind your mirror blank to the correct curve. Start in the centre with the small grinder and expand out with the medium grinder.

Step 2

During smoothing and fine grinding, use the full-diameter, tiled grinding tool with finer 220- and 320-grade carborundum powder and then the 125- and 50-grade emery powder. Move the blank over the grinder and make your grinding strokes short.

Step 3

Make the pitch lap, the traditional method of polishing. Pour melted pitch 1-inch deep onto the full-diameter grinding tool, then press it onto the roughly ground blank to mould it to the same curve. Using a ruler, make grooves in the pitch to aid polishing.

Start smoothing with the 220- and 320-grade powder, switching later to emery powder for the fine grinding. At this stage, grinding strokes must be kept short: this keeps the blank and tool perfectly matched in order to produce a spherical curve. Fix the grinder to the surface and move the blank around it using the classic grinding technique. Try to produce as few scratches as possible, but even a few dozen won't affect the mirror's performance much.

You need to make a 'pitch lap' with pitch or bitumen for the polishing stage. The pitch has to be slowly heated and then poured over the full-sized grinder so it's about an inch deep. While it's still malleable, press the blank onto the pitch, to mould it to the blank. When polishing, keep your movements short and sprinkle small amounts of cerium oxide polishing powder in the centre. When using the pitch lap, the blank will bed into the pitch and slowly wear away any small dips made by the previous grinding stages. Because of the friction, the pitch lap has to be held on a suitable board with retaining clips.

Fine tuning

As you start to get a good reflection, you need to test the blank to see how it's shaped up and where the surface may need correcting – a process called figuring. For this, make a simple mirror tester, which will cast shadows on the blank and reveal where it needs more figuring work. Do this regularly to check the surface of the blank and polish it to remove any errors. Once you're satisfied with the curve's smoothness, all you need to do is get the front aluminised. You can't do this at home, but the Camden Amateur Telescope Making Society can put you in touch with people that can do it for you. After that, the only thing left to do is to fit the mirror into your telescope.

MORE ONLINE

Find full instructions for this project online at www.skyatnightmagazine.com/bonuscontent

TOOLS AND MATERIALS

Carborundum stone
To smooth off the edge of the mirror during grinding.

Grinding powders
A range of coarse to fine carborundum (silicon carbide) powders, grades 80, 120, 220 and 320; emery powder: 125 and 50 grade (equivalent to 600 and 900 carborundum); polishing powder and cerium oxide.

Grinding tools
Use any heavy, small-diameter metal object for the small and medium rough grinders, such as the head of a hammer or a small dumbbell weight. Alternatively, use ready-mixed mortar to make circular grinders about 2 inches high. The small one should be 3 inches wide, with steel nuts inset for the grinding surface. The medium rough grinder is about 4 inches wide, also with small steel nuts inset for the grinding surface. Use mortar to make the fine grinder and polisher, which is the full diameter of the blank. Stick small ceramic tiles on with tile adhesive to make the grinding surface.

Mirror blank
An 8.5-inch (215mm) diameter mirror blank, available from the Camden Amateur Telescope Making Society, visit bit.ly/2E9CAkD.

Mirror tester
A small filament torch bulb, battery, a straight edge and some wood.

Notebook
To keep track of grinding and polishing times and to keep a log of the final figuring.

Pitch lap
Pitch, an old saucepan and a small camping stove.

Washing-up bowl
To wash the mirror during rough grinding.

Step 4

When polishing with the pitch lap and polishing powder, use the same small strokes as you did when fine grinding. This brings the mirror blank's surface back to clear. Check the pitch lap regularly to make sure that it matches the shape of the blank's curve.

Step 5

To make the mirror tester you need a small bulb, battery and a straight edge. Shine a light on the blank to reflect back to the straight edge. Then move the straight edge sideways to cut off the reflected light. Shadows appear on the blank to reveal its shape.

Step 6

The last process is figuring. Use the pitch lap to 'parabolise' the blank's surface. Polishing away extra glass shortens the focal length towards the centre. This ensures a perfect focus when aimed at the sky. All that remains is to have a mirrored surface added.

Our finderscope is easy to build from old binocular optics and off-cuts of plywood, plus a handful of small components that are easy to find in any DIY store

Make a finderscope

By Mark Parrish

Ensure your celestial targets are always in the right place with this home-made finderscope

On the previous pages in this section we've shown you how to upgrade various parts for a telescope and even make a Dobsonian scope. Now we'll show you how to make a finderscope to complete your setup. You can fit this device to any telescope that lacks a full-sized finder. This design bears a slight resemblance to the wooden box-tubed Dobsonian telescopes popularised by John Dobson. We've designed the finder using an approach similar to the one he followed: it's made from binocular optics mounted in a simple wooden tube.

The optics

Go to any car boot sale or charity shop and you'll find at least one pair of binoculars. They might show signs of wear but they're a good source of optics for the short refractor at the heart of our finderscope. The 10x50 pair we found only cost £3; it had one damaged objective lens but the other looked clear and both eyepieces seemed intact. Fifty millimetre objective lenses let in plenty of light and are quite common, but the design can easily be adapted to suit other sizes.

Once you've dismantled the binoculars you need to make a simple test frame to hold the objective and the eyepiece lenses in line. Look through the setup and slide the eyepiece back and forth until you can focus on a distant object, such as a lamp post at night. The distance between the objective and eyepiece lenses determines the length of your wooden tube. Most binoculars have one adjustable eyepiece to accommodate any discrepancy between your eyes. Use this one if you can, as you can then utilise its fine-focus mechanism for adjusting your completed finderscope.

The woodworking required for this project is straightforward. Once you've cut the main box sides and drilled the holes, all the parts are simply glued together. A good matte-black lining improves the finderscope's performance, so apply this before fixing on the top panel. Also check the spacing of the optics by putting them in place and looking through them at regular intervals during the build.

We chose 6mm plywood for the main body, as it's easy to work with and strong enough to cut intricate shapes out of. All the parts can be cut by hand, but if you have access to an electric scroll saw, this can make short work of the holes for the objective lens and eyepiece. You can find the full plans for the finderscope at www.skyatnightmagazine.com/bonuscontent, but you may need to adjust some of the dimensions to suit your parts.

TOOLS AND MATERIALS

Tools
A coping saw or scroll saw; a drill with 5mm and 8.5mm bits; small pliers or cutters; a screwdriver and a spanner to suit the M5 components.

Timber
A small off-cut of 6mm thick plywood (roughly A4 size) and a small piece of 9mm plywood. Other materials such as MDF may work, but not chipboard.

DIY store parts
Two M5 x 60 countersunk bolts; six M5 nuts; four 18mm domed rubber tap washers; wood glue; super glue; paint or varnish; a small piece of thin wire.

Binocular parts
Objective and eyepiece assembly from a pair of medium-sized binoculars (10x50 is a good choice).

ALL PICTURES: MARK PARRISH

All finderscopes need a reticule (an internal crosshair or marking with which to aim). These can be fiddly to fix into the eyepiece, but we've designed a bent wire 'W' reticule that is simple to insert. It looks unconventional but works nevertheless.

Experiment to find the best position and fix with superglue if necessary.

Fixing and finishing

The mount consists of an adjustable platform that's clamped to two threaded bolts. There are two thumbwheels that can be screwed up and down to loosen the mount for movement and clamp it tight after. You can use these to raise or lower the finder and also swing it from side to side. Adjustments can all be made from one place and the domed rubber tap washers ensure nothing slips.

The paint finish protects the plywood from moisture, but you may prefer a stain or varnish finish to suit your telescope. Don't paint it while it's assembled, though, or the moving parts will get stuck.

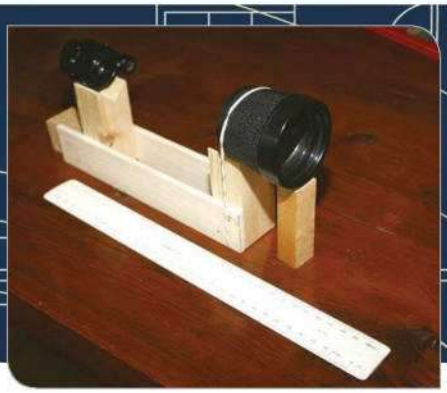
Mounting the finderscope on a flat-sided telescope is a simple matter of drilling holes for it and screwing it in. If you have a round tube you will need to introduce some packing strips to suit the curve. Once everything's assembled, you will need to turn the alignment screws so that when you see a bright star in the centre of the telescope's field of view, it aligns with the centre point of the reticule.

Once your finderscope is correctly aligned, you'll soon be pointing your telescope with improved accuracy.

MORE ONLINE

Download and print pictures and cutting diagrams for the finderscope

STEP-BY-STEP



Step 1

Once you have dismantled your binoculars, you need to make a temporary frame to hold them in line. Slide the lens and eyepiece back and forth until you can focus on a distant object. The distance between them determines the length of the wooden box case.

Step 2

Use a coping saw (or electric scroll saw) to cut out the plywood sections. A bench vice is useful for holding the small pieces steady. Make sure the holes for the optics are accurate. Place the lens and eyepiece and test the position of the optics before gluing.

Step 3

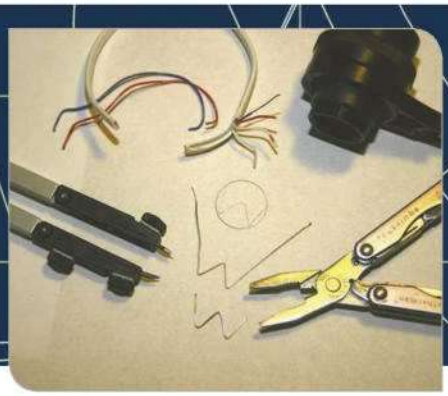
Use clamps or tape to hold the case parts together while the glue sets. PVA glue works fine, but you could use epoxy adhesive for speed. We didn't glue the top of the box on, so we could access the insides for painting and fixing to the mount later on.

Step 4

After cutting the plywood thumbwheels, drill 8.5mm holes in the centre of each. Then press-fit an M5 nut into the holes and secure them with a few drops of superglue. The upright bolts should be countersunk into the bottom of the base and secured with a nut.

Step 5

Once all the woodwork has been done, you can sand the individual parts smooth and paint them. We used an assortment of paints, wood stain and varnish to match our telescope. Separate all the parts before painting or they will stick together.



Step 6

The reticule is made from thin, soft wire. We found some by stripping an old telephone cable. Measure the internal diameter of the eyepiece and then draw it to size on some paper. Use this as a guide for bending the wire to the correct shape and size.

Make a small refractor

Reveal the wonders of the Solar System with this easy-to-make telescope that'll cost you less than £100

By Mark Parrish

You'll have an added sense of achievement when you spot Saturn's rings with a refractor you've built yourself

Small refractors are light and portable. What's more, their optics need little or no adjustment so they're ideal telescopes for beginners – and easy to build. Best of all, building one shouldn't even cost you £100.

The heart of any refractor is its convex glass objective lens, which is mounted close to the front of the telescope tube. Rays of light from distant objects such as the Moon pass through this and are bent, or refracted, towards a point just inside the back end of the tube. This point is the objective lens's principal focus and the distance from here to the centre of the lens is called the focal length.

At the opposite end of the tube to the objective lens is the eyepiece, arranged so that its principal focus coincides with that of the objective lens. If you don't have one, a 1.25-inch Plössl eyepiece will cost you around £25. The eyepiece refracts rays of light into your eye. A telescope's focuser allows small adjustments to be made to the distance between the eyepiece and objective lens to accommodate different sizes of eyepiece and the standard of your eyesight. The eyepiece usually has a much shorter focal length, which means that the final image is magnified. To calculate the magnification, divide the objective lens's focal length by the eyepiece's: an objective with a focal length of 400mm and an eyepiece with 10mm will magnify 40x.

Lenses and tubes

The aperture of the objective lens is larger than that of your naked eye, which means it can capture more light. The first telescopes consisted of a single convex objective lens with a concave eyepiece lens at the other end. Unfortunately, not all wavelengths of light refract uniformly, so the image of a bright star might appear blurred and suffer from a distracting coloured halo around it.

To overcome this problem, modern telescopes have what are known as doublet lenses. These are made up of two glass elements that work with each other to bring most of the colours to focus at the same point. This type of lens is called an achromatic objective and is what we'll be using in the telescope that we're building in this project.

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Eyepiece and tripod

To use your telescope you'll need an eyepiece. A medium focal length (say 20mm) 1.25-inch Plössl type is a good choice. With a little ingenuity you can adapt the lens test stands to make a mount to fit a standard camera tripod.

Focuser

For the sliding focuser you need an offcut of 43mm diameter plastic waste pipe about 160mm long. You also need a small piece of flat timber (plywood, MDF or softwood) for the end of the main tube.

Main tube

Find some tube with a diameter that's larger than your objective lens. It needs to be at least as long as the objective's focal length – find out how to measure this in the main article. You also need about 125mm for the dew shield. We used some 110mm plastic drainpipe.

Objective lens

The exact specification is up to you, but a 60-80mm objective lens won't cost you much to buy from a surplus store. Alternatively, you may be able to extract an objective lens from an old projector, camera, photocopier, or even a damaged telescope or pair of binoculars.

Tools

You'll need a handsaw/hacksaw to cut the tubes and a coping saw for the round wooden end. Also matchsticks, mastic glue and electrical tape.

Unlike mirror making (see page 52), grinding and polishing an achromatic doublet lens is not something most amateurs would consider. Thankfully, achromatic lenses are relatively easy to come by and can be surprisingly cheap – around £20 for a 60mm lens. There are a number of surplus companies that offer mounted telescope objectives – a quick online search will provide you with plenty of options. You may even have a pair of broken binoculars with one salvageable objective lens. The other parts for this scope can be made from plastic pipe that you can buy from a builders' merchant for about £20, or get from a friendly plumber.

The first stage of the build requires you to measure the focal length of your lens. The easiest way to do this is to make a simple wooden stand for the lens (see Step 1, right) and another with a sheet of white card fixed vertically to it. Align these on a flat surface so the view through the lens is projected onto the card. Then aim the lens at a distant object – the view through a window works well – and move the lens back and forth until a focused, upside down image of the outside world appears.

Measuring the distance between the glass of the lens and the card gives you an approximate value for its focal length, which will help you determine the rest of the dimensions for your telescope. Use these measurements in conjunction with the plans for this project in the bonus content (www.skyatnightmagazine.com/bonuscontent) to calculate the tube lengths you need and then start sawing.

Aim for the heavens

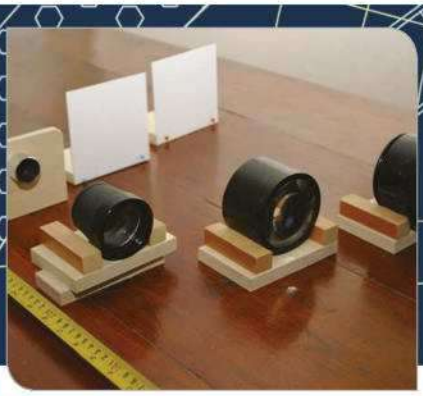
You can hold the finished telescope for terrestrial use (slide the focuser back and forth to achieve good focus), but for astronomical observations, you'll be better off mounting it on a tripod. We adapted one of the lens test stands we made earlier with foam and a luggage strap to mount our telescope (see main image, opposite). You may eventually want to get a small altaz or equatorial mount for your telescope. With the latter, you'll be able to guide it precisely by small movements of the slow-motion controls.

With your new refractor you can look for the small telescope targets suggested in the monthly Sky Guide published in every issue of *BBC Sky at Night Magazine*.

MORE ONLINE

Download and print detailed plans and schematics for this project

STEP-BY-STEP



Step 1

To identify the principal focus of your lens use wooden stands and some card to project an image of a distant object. Measure its focal length. Use this measurement with the plans in the bonus content online to work out the tube length.

Step 2

Carefully cut the main tube with a suitable saw. Wrapping a sheet of paper around the tube is a good way to mark a straight line. Take care here – perhaps get someone to help hold it steady as you saw. Cut a second piece and split it lengthways.

Step 3

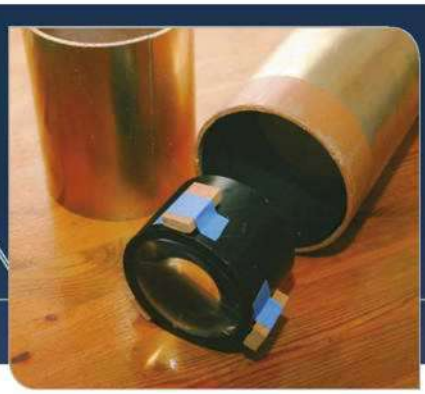
Cut three lengths of 43mm pipe to make the sliding focuser. Split the shorter sections and remove a strip from one so it fits inside the larger piece (a couple of matchstick spacers help the eyepiece fit snugly); the other will stretch to fit around the outside.

Step 4

Draw round the inside of the main tube on a suitable piece of wood. Cut out with a coping saw for a tight fit in the tube. Mark the central hole by drawing round the assembled focuser, then drill and cut out the hole for the focuser tube.

Step 5

Paint the inside of the tube and dew shield black with paint. Apply some mastic glue around the focuser and the wooden end, and the main tube when assembling. Decide what packing is needed for the objective to fit tightly inside the tube.



Step 6

Cut a ring of plywood or make three packing strips and position these between the objective and the inside of the tube. Fix them into position with a little tape or mastic glue. Fit the dew shield and cover any gaps with tape.

OBSERVATORIES

With an enclosure for you and your scope, you'll be able to step out of your back door and start an observing session in seconds. Use the plans on the following pages to build a permanent base for your stargazing

BACKGROUND IMAGE: ISTOCK, ROBERT LUCAS, MARK PARRISH, STEVE RICHARDS

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Modify a shed to protect your scope pillar

By Robert Lucas

Guard your pillar from rain and wind with this low-tech shed mod

ALL PICTURES: ROBERT LUCAS

▲ When you want to use your scope, simply open the shed's doors and wheel it out of the way

Having a run-off shed enclosing your garden telescope pillar is probably the next best thing to building a dome observatory, though it is very much cheaper. This entire design should cost you around £300. It is also quick to set up, as rapid as opening and positioning the shutter of a dome. The shed is entirely weather proof and offers some degree of security for your kit, so you may leave your scope permanently attached to the pillar.

You don't have to build the shed from scratch: this project is to modify a commercially bought plastic one. The shed used here is 1.98m high, has a width of 1.51m and is 0.83m deep, though it could also have been made deeper by adding an optional middle segment. The modification is straightforward – simply cut out a section of the shed floor so that it can enclose the pillar when the doors are shut. We're going to mount the shed on a sack barrow, bolted to the structure's rear. This allows you to lift the shed and wheel it away from the pillar when you want to use your telescope.

We've used a shed of this size to house a 300cm Schmidt-Cassegrain on a custom

STEP-BY-STEP

Step 1

Measure the diameter of your pillar and add 1cm. Using a ruler and compass, mark the area to cut out on the base of the shed. This area should extend to a radius past the middle of the shed, so that the pillar is central to the shed.

Step 2

Use an electric or hand fretsaw to cut out the part that goes around the pillar. Be careful of the reinforcing plastic cross pieces on the bottom side. You may need to go out slightly wider to avoid these. Smooth any rough edges with the sandpaper.

Step 3

Assemble the rest of the shed according to the manufacturer's instructions. Assemble the sack barrow if necessary. Place the sack barrow at the rear of the shed with its bottom plate under the floor of the shed and align it accurately with the centre of the shed.

"You don't have to build the shed from scratch: this project is to modify a commercially bought plastic one"

▲ With the doors closed, the shed keeps your gear secure and protects it from the elements

equatorial mount. If your scope is larger, you should probably consider a deeper shed, or one that can be extended by adding optional middle panels. If you have yet to install a scope pillar in your garden, you should think carefully about what height this is going to be. Remember to take everything into account: the pillar, the adjustable mounting plate, a mount that is almost certainly going to be equatorial, then the telescope and possibly a dew shield. The last of these can usually be taken off, of course, if space becomes an issue.

You may wonder why the shed is mounted on a sack barrow rather than wheels. It's true that wheels work perfectly well, but the gap at the bottom that is necessary to accommodate them could let moisture in. Using a sack barrow means that the floor of the shed sits directly on the concrete apron supporting your pillar, forming a reasonable seal that prevents any water ingress. This also makes the shed less likely to be blown about and damaged, as wind cannot get underneath it. Cutting out a slot from the floor to fit round the pillar does weaken the floor's structural integrity, but not having to attach wheels also means that there is no need to take steps to strengthen it.

Cooling option

When closed, the inside of the shed can become rather hot at the height of summer – especially in parts of the world at more southerly latitudes than the UK. Depending on your local conditions, you may want to fit a solar-powered fan to stop the build-up of hot air. This is extremely effective, as the hotter the weather the faster the fan rotates. However, this is an optional add-on.

The shed can also be used to house your other essential accessories and even a small table or shelf for a laptop. We have hooked ours up to a mains supply, which is fed in through a small hole in the shed and is then connected to the mount's power supply. As the shed needs to move to reveal the telescope, it may be necessary to introduce some slack in the cable. The right amount can be found and then the cable knotted at that point inside the shed so that it can be repeatedly run out to the length required.

One safety note: when you come to move the shed using the sack barrow, you need to place one hand on the top of the shed, one on the barrow handle and a foot on the axle to maintain proper balance.

TOOLS AND MATERIALS

Materials

Plastic shed kit, sack barrow, two 80 x 40cm or larger pieces of 0.25-inch plywood, electric fan (optional) and solar power cell panel (optional).

Tools

An electric or manual fretsaw, geometry compass, yellow or white pencil, ruler, 40-grit sandpaper, paint brush.

Sundries

Four U-bolts to fit the sack barrow with washers and nuts, varnish or external wood treatment, yellow or white paint.

Step 4

Place the plywood on the inside and outside of the shed and drill eight holes for the U bolts, deep enough that they go around the tubing, through the exterior ply, the plastic and then the internal ply. The wood spreads the load to protect the plastic.

Step 5

Thread the U bolts through the drilled holes from the outside. Put washers and nuts onto the threaded parts of the bolts and tighten each a little at a time. It's important to get the amount of tightening correct – over-tightening will damage the plastic.

Step 6

With the shed perfectly placed over the mount, mark the rear corners and a straight line with bright paint showing the way back to the 'home' position. This is very useful, as you will be 'driving blind' from the rear of the shed when you move it.

BIG BUILD

Build your own OBSERVATORY Part 1

By Mark Parrish

Pick the right site and establish the foundations of your home-built observatory

You can't beat a night under the stars with your telescope, but this usually involves lugging heavy equipment outside and assembling it, by which time you may find that the clouds are rolling in. With a garden observatory at home, you simply open the roof and in a few minutes you're stargazing. When it's time to stop, just close up and head indoors.

There are many styles of home observatory. Commercially made glass-reinforced plastic domes are an instant – although expensive – solution, but home-built options also include apex-roofed sheds with roll-off or lift-off roofs. If space is tight you can make a small enclosure that rolls back on wheels. Every style has its merits and drawbacks, but the great thing about designing and building your own is that you choose the best size, layout and appearance for your situation.

In this four-part guide we'll show you how to build a domed-roof observatory, ideal for a site with strong winds, local light pollution and limited space.

In this first part, we look at how to pick a location and cast the concrete foundations. On the following pages we'll cover creating a framework for the walls and floor; constructing the dome; and finally fitting out the interior. The construction methods and principles we describe can be used with other designs, and the materials and techniques will be familiar to anyone with DIY experience. So read on and soon you'll be observing in your own miniature Kitt Peak.

Location, location

Before starting, you need to carefully consider the siting of your observatory. Spend several nights with your telescope on a portable mount, trying different spots in your garden. Remember that for planetary and lunar observations a clear view of the southern sky is essential. Could growing trees block your view? Do house lights cause a nuisance? Is the site secure? Make a note of the best position and decide how high the mount should be.

Once you've resolved these practicalities, check that you have permission to build. With the aid of sketches or photos of similar projects, talk to your family – especially if a favourite flowerbed will require 'modification'! It's also a good idea to check with your local planning authorities. Temporary structures less than 3m tall are usually allowed, providing that they're not too close to buildings or beyond the

Carefully marking out the observatory now will help prevent problems later on

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Marking out tools
A tape measure is essential, as are a spirit level and string.

Mixer and barrow
Hire a cement mixer and use a wheelbarrow to transport wet concrete.

Pegs
Make pegs from 1 x 2-inch timber.

Shuttering board & tools
A handsaw, hammer, nails and a selection of plywood or chipboard pieces.

Spade and shovel
A spade and a shovel for shifting ballast and concrete.

boundaries set by building lines. A chat with the planning department may be all that is required. Inform your neighbours as well – a good relationship will help things run smoothly. If they feel involved, they'll more readily understand any future requests to trim bushes and turn off security lights.

This design has eight concrete pads below the wall posts and a large block (almost 1m^3) for the central pier. Bolting the mount to this solid mass of concrete keeps it aligned and stops vibrations at the eyepiece when walking around on the floor above. Because the floor is raised, additional shuttering (wooden support) was used to provide a short column on which to fix the steel pier. Eight M12 threaded rods 1m long were cast into this column to provide reinforcement, and 50mm lengths were left sticking up to which the pier base was bolted.

Sawing and nailing together the shuttering, and mixing concrete is hard but rewarding work. Neatness isn't vital, but do ensure that each surface is level and smooth to avoid problems later on. We used 1.5m^3 of ballast and 12 x 25kg bags of cement, mixed in a ratio of about 6:1. While you're waiting for the concrete to harden, you can begin preparing the timber sections. Once your foundations are laid, follow the steps on the next pages to find out how to construct the wooden framework for the walls and floor.

TURN THE PAGE FOR PART 2 ▶

STEP-BY-STEP

Step 1
Carefully mark out the ground using wooden pegs, straight poles and string. Peg tops, used as a reference for the top of the concrete, should all be hammered down to the same level and checked with a spirit level resting on a long bar.

Step 2
Dig the pad holes (400 x 400 x 400mm) and central pier hole (900 x 900 x 900mm). If you dig the holes carefully you may not need any shuttering, but offcuts of timber or plywood nailed together can be used to keep the edges neat.

Step 3
Here we've used chipboard to make shuttering, which gives the concrete neat edges and sides. Make a frame to hold the eight 1m-long threaded rods in place while the concrete in the central pier base sets. Use a spirit level for accuracy.

Step 4
A cement mixer (and plenty of help) makes mixing the concrete easier. Protect grass and plants from cement dust. Add enough water to make a 'dropping' consistency similar to thick porridge. Wash all of your tools before the concrete on them sets.

Step 5
Pour in the mix and pat it down to remove air pockets. Top up to the correct level, then use a trowel to smooth the surface. Make a square frame to form a lip on top of the pier base. This will help you align shuttering for the top part.

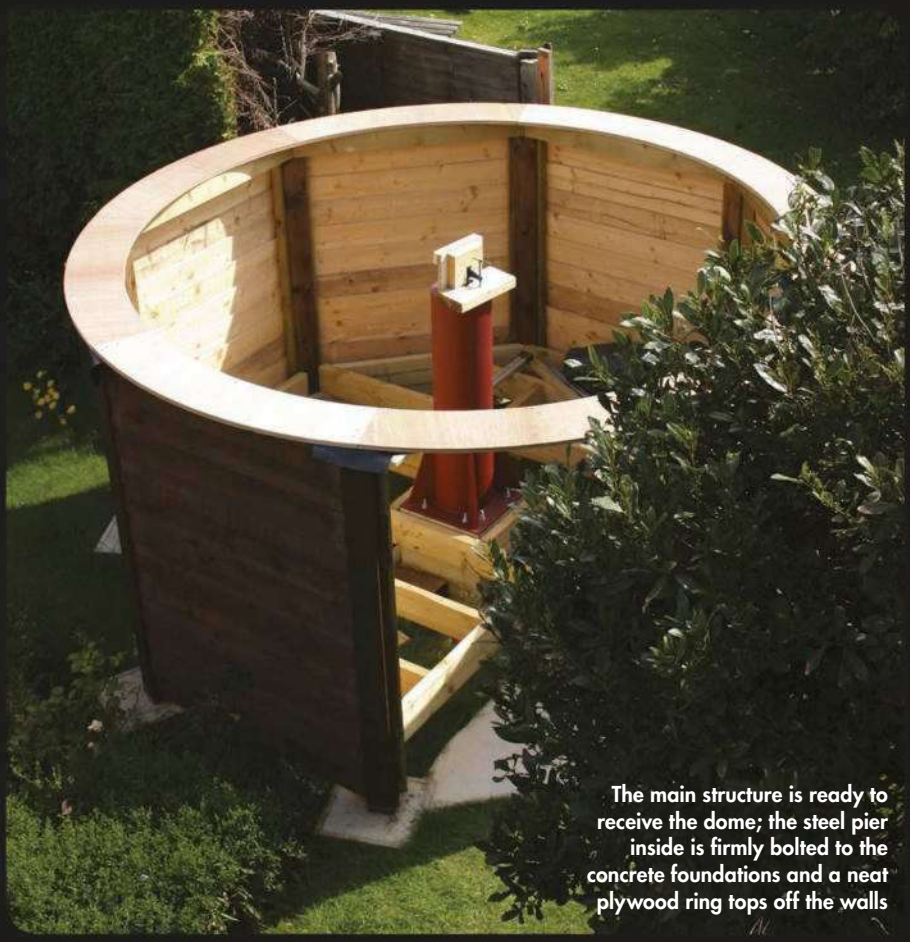
Step 6
Once the concrete begins to set, fit your frame around the upper section of the pier and pour in the remaining concrete. The shuttering can be carefully removed after a couple of days, but don't chip any edges, which take much longer to go hard.

BIG BUILD

Build your own OBSERVATORY Part 2

How to turn your stack of timber into the beginnings of a building

By Mark Parrish



The main structure is ready to receive the dome; the steel pier inside is firmly bolted to the concrete foundations and a neat plywood ring tops off the walls

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Power tools
A circular saw, router or jigsaw for cutting the wood. You can hire these tools.

Timber
1,800 x 100 x 100mm treated softwood for the eight wall posts, 1,000 x 150 x 50mm timber for the floor joists, 1,000 x 100 x 50mm timber for the joist supports, 1,000 x 100 x 23mm for the top bracings, a sheet of 18mm plywood for the top ring and 24m of 50 x 50mm softwood for the cladding battens.

Woodworking tools
A handsaw, plane, hammer and screwdriver, plus nails and screws.

Once all the concrete work is complete, you can start work on the observatory's walls and floor. This doesn't involve any complicated joints, just careful cutting and fixing with screws and nails. You may need some help to erect the posts, but once they are upright, construction is fairly straightforward.

The eight posts have wooden strips on either side, to which the wall cladding will be fixed. They also have hardwood blocks attached that hold the joist support beams, plus pads on the bottom. We used hardwood offcuts for these pads, but you could try thick plastic or ceramic tiles – anything that separates the wood from the damp ground.

You should first loosely erect the structure and then make adjustments so that the posts are evenly spaced and upright. An offcut of wood bolted to the central column provides a useful reference point to take measurements from. Tap a nail into it and you can use a length of string to ensure all the posts are the same distance from the centre of your observatory. If some of your concrete pads aren't quite level, you can add a little packing under the relevant posts. When you're happy with the alignment, screw all the parts tightly together. A powered screwdriver is a great help here.

Floor-less vibrations

Fit the joist supports between the posts, then you can start on the floor joists. The first ones to position are the long ones either side of the central pier base. Leave a gap of about 10mm between the concrete base and the wood so that vibrations from you walking on the floor aren't transferred to the telescope.

We used 75mm woodscrews, screwed in at an angle of about 45° from either side, to fix the joists onto the supporting beams. Next, fix a joist at right angles to form the step. The remaining joists are placed at an equal spacing (about 400mm apart) until you reach the edges. Some angled cuts are needed at the edges or else the wall cladding may not fit properly.

In between the main joists, nail short sections of the same timber to brace the structure. Our joists were 50mm wide and 150mm deep, but if you want to calculate your own depth, use this

▲ A jig was built for the router to cut the eight curved sections for the plywood ring on top of the observatory walls

formula as a guide: depth in mm = [(span in mm ÷ 600) x 25] + 50. We decided not to fix the floorboards to the joists until the dome was in place, as rainwater could damage them.

Next, cast a simple concrete floor under your step. You could use gravel patch or a simple paving stone instead, but the idea is to help to stop muddy footprints getting into the observatory during wet weather.

For cladding we used sawn and treated 'feathered edge' fencing boards. These are screwed onto 50 x 50 vertical battens (fixed to the sides of the posts) with an overlap of about 30mm, starting close to ground level with the thin edge at the top. A smoother, but more expensive, option is interlocking tongue-and-groove board, and a cheaper option is plywood; the choice here is a personal one because the outward appearance will be different for each. We applied a dark brown preservative paint to the outside. If you line the inside of the observatory with plywood or coated hardboard panels, it provides a smooth surface for putting up your sky charts and astrophotos.

Finally, cut the eight sections of the plywood ring that fits around the top of the wall posts. This ring provides a fixing surface for the dome wheels and also serves as a shelf for eyepieces and cups of tea. We made a jig (a frame to hold a piece of wood in position) that enabled us to cut the plywood sheet to the required radius using a router, but it could also be cut with a jigsaw.

At this stage you should bolt the steel pier to the central concrete column. The top of the pier was used to hold our router on its jig in order to trim the ring to a perfect circle once the pieces were screwed onto the tops of the wall posts. With the ring in place, don't forget to cover up your construction with plastic sheeting to protect it from rain while you prepare for the next phase.

TURN THE PAGE FOR PART 3 ▶

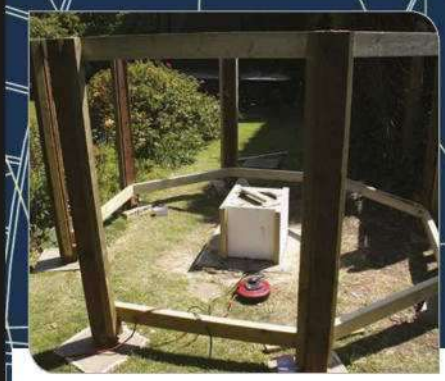
STEP-BY-STEP

Step 1

Cut sections of timber for the eight posts, floor joists, joist supports and top bracing. A circular saw will make short work of the angled cuts, but these can be done with a handsaw. All our timber is pre-treated, but freshly exposed cuts require preservative.

Step 2

Screw together the sections for each post. Use galvanised coach bolts to hold the hardwood blocks that will support the floor and hardwood pads below the posts as they are more water-resistant. Coat all the wood with preservative.

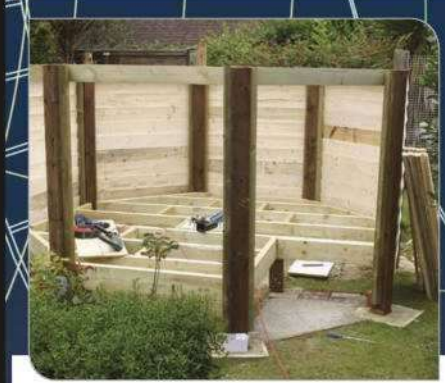


Step 3

Assemble the posts and joist supports. Use one woodscrew for each joint at first, to allow small adjustments to be made. All posts must be upright and evenly spaced. Add the top bracing beams once the bottom of the structure is fixed together.

Step 4

Cut the floor joists and fix them into place. Make sure to leave a gap between the central pier base and the joists to prevent vibrations. Short sections of joist between the main lengths stiffen up the structure. Note the gap on the left for the step.



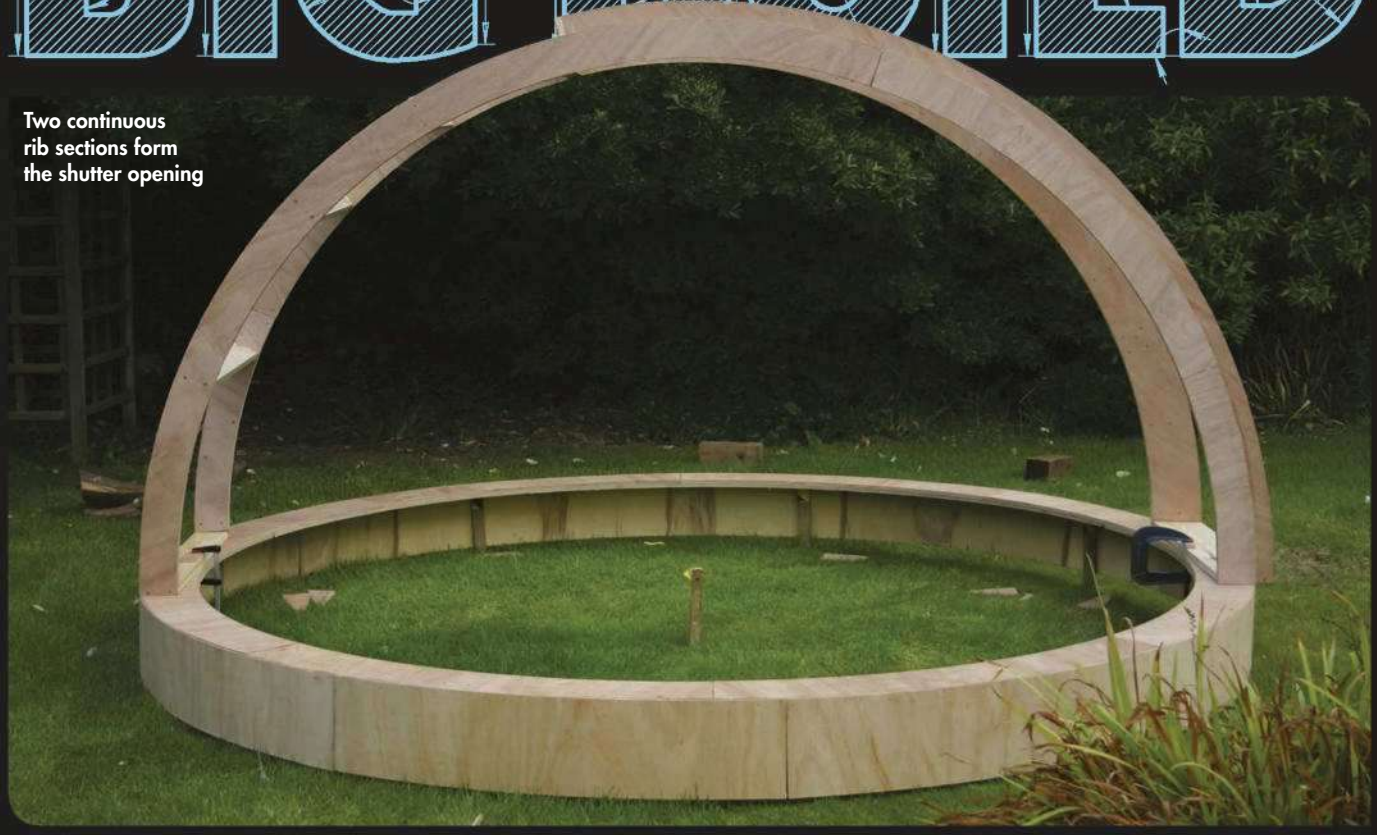
Step 5

Nail the wall cladding boards between the posts. Start at ground level and work up, trimming the top board if necessary. Note the optional cast concrete floor inside the entrance to the observatory. The short post under the step provides support.

Step 6

The steel pier is bolted to the column using the protruding threaded rods. Clamp a wooden block temporarily to the top of the pier (see image opposite) to hold the router and help you position and trim the sections of the ring on top of the walls.

BIG BUILD



Two continuous rib sections form the shutter opening

Build your own OBSERVATORY Part 3

By Mark Parrish

Now it's time to assemble the rolling roof that will protect your telescope

The third part of this observatory project – building the hemispherical dome – is not as tricky as you might think. The curved ribs are cut using a simple jig that you can make yourself, and because the dome will be coated with a strong, glass-reinforced plastic (GRP) layer, you can get away with a few gaps.

It's important to build the dome on a level surface, so that it rolls around smoothly on its runner when fitted. Building ours, we supported it on a ring of level wooden pegs hammered into the lawn. A central peg with a string line is useful for checking that the shape is circular as work progresses.

Spend some valuable time making a jig to hold your router or jigsaw. We made a frame on which to rest the sheets of plywood and added a long swinging arm. Our router was clamped at various positions along the arm to cut different sections.

The main ring is made from two layers of 12mm plywood, and each layer is made from eight segments. Glue and screw the layers together with the joints staggered to form a rigid, 24mm thick ring. A thin plywood skirt was glued and nailed to the outside edge. If you use raised pegs to support the ring, the skirt doesn't have to take any weight during the dome's construction.

Next, two continuous rib sections were cut to form the shutter opening. These were reinforced with a second layer of plywood that protrudes around the opening to form a lip that keeps the rain out. Two similar ribs were then added at 90° to the shutter ribs. We used pre-drilled steel brackets and screws to fix them at the top and bottom. Temporary wooden spacers inserted between the shutter ribs kept the opening parallel.

The four remaining ribs were cut from one layer of plywood and fixed at 45° to the shutter ribs using butt hinges. Because of the geometry, the hinges don't move, and using them means you don't need to make a tricky joint.

Putting it all together

Adding the hardboard skin is easier with an extra pair of hands. We held a whole sheet in place over the relevant ribs and traced the shape from inside with a pencil. Then we cut out each panel using a jigsaw and held it up to the ribs to check the shape, before gluing and nailing them in place. A similar technique is used to make the two sections that form the shutter. Tubes of gap-filling adhesive (available from builders' merchants) are excellent for this.

Once all the panels were fixed, a generous squirt of glue was used to seal and reinforce all the joints, and any rough edges were sanded down.

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Glass-reinforced plastic (GRP)
We used chopped strand matting to cover the dome and reinforced the joints with chopped strand tape. Resin bonds the matting together.

GRP tools/equipment
Mixing buckets, old rollers and brushes, acetone, safety gloves, overalls.

Power tools
A router or jigsaw to cut the curved plywood parts of the ring.

Timber
12mm plywood for the ribs and main ring. Thin (3mm approx) plywood for the skirt and the shutter skin. 3mm hardboard for the main dome panels.

Rough-sanding the whole surface helps the GRP resin to make a good bond.

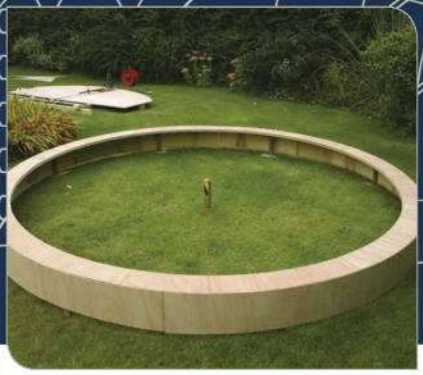
Adding the GRP layer is fun, but messy and sticky. Read the manufacturer's safety guidance, work in a ventilated space (preferably outside) and avoid contact with bare skin. The process involves applying resin to the whole surface, sticking strips of GRP matting over each joint to make them smoother and stronger, then sticking a layer of GRP matting over the whole surface of each panel, working it into the resin with a roller.

Lastly, we applied a layer of grey gel coat, which seals the surface and provides the required colour. When this is set, there may be trimming and sanding to do, but the dome will require no further finishing and becomes rigid, waterproof and strong.

Our dome runs on eight pairs of castors, with one of each pair supporting the dome and the other facing outwards to guide its revolutions. Once all the castors are fixed to the wall ring above each post, enlist the help of friends to lift the dome onto the structure. We found it easiest to lift and manoeuvre the dome when it was supported on two aluminium ladders. One team lifts it from outside, while those inside take the weight as the ladders are slid away. Then the dome is slowly lowered onto the castors.

TURN THE PAGE FOR PART 4 ▶

STEP-BY-STEP



Step 1
Build a double-thickness plywood ring, supported on wooden pegs. The joints are staggered to improve the strength. Bend thin plywood around the edge to form the skirt. Run a length of string from a central peg to check the shape is circular.

Step 2
The two main ribs are screwed to the main ring using metal brackets. A raised lip around the shutter opening is formed by an inner layer of plywood. The rear spacers will stay in place, but temporary spacers will help to keep the opening parallel.

Step 3
Three further ribs are fixed on each side of the main ribs. We used normal hinges to join them at the top and bottom. Cut the ribs a little long, then trim them to suit the position. A stepladder comes in handy for reaching the top.

Step 4
Cut out the hardboard panels and fix them to the ribs with nails and gap-filling adhesive. The panels will form curved 'facets' rather than a perfect hemisphere. Sand down any ridges, then use more adhesive to reinforce joints and fill gaps.

Step 5
Roughen the surface of the hardboard, then coat with resin, chopped strand matting and more resin. Don't mix too much resin at a time or it will set in the bucket. Work it in well using rollers and complete the job with a coloured gel coat layer.

Step 6
Above each post, eight heavy-duty 100mm fixed castors with rubber tyres take the weight, while eight smaller horizontal castors, held by steel brackets, guide the dome around. Once these are in place, the dome can be lifted on.

BIG BUILD

Build your own OBSERVATORY Part 4

By Mark Parrish

You're almost ready to start exploring the night sky

The completed observatory ready for use; the fully opened shutter provides clear views of the sky

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Decorating equipment
Rollers and brushes, black emulsion paint and varnish, gloves and overalls.

Electrics
A pair of mains outlets, dimmable red lights, white lights, buried armoured cable and a protective RCD device, telephone and network cable.

Timber
18mm floorboards (either tongue-and-grooved or plain), thin plywood or MDF (3–6mm).

Tools
Hand tools for cutting and fixing the floorboards.

Now that your project looks like a completed observatory, you'll be anxious to get inside and start observing. However, there are still a few final details to get sorted. Here, we'll cover the finishing touches that will help you to set up your observatory for maximum satisfaction.

First comes the shutter, which is made in two sections. The main section rolls back beyond the opening, allowing a clear view overhead. In order to see down to the horizon, the lower section can be lifted out. The shutter's main section is fitted with small, fixed castor wheels that run directly on the dome's surface. Additional wheels, mounted sideways between the inside edge and the lip around the opening, guide the shutter while closing. You could open and close it with a long pole, but for a touch of sophistication we opted to install a pair of pulleys and a strong cord to operate the shutter. We used a cleat to tie off the cord and hold the shutter closed when not in use.

Although the dome and shutter are heavy, it's important to provide methods to keep them in place during strong winds. We used sliding bolts to secure the shutter and four long, bent strip hinges that flap down over the wall ring to stop the dome lifting.

A step is desirable if your floor is high. We opted to build a step to bridge the distance between the ground and the floor, and we also fitted a useful doormat (as you can see in the open doorway of the observatory, above left). Fortunately, we have never fallen down the step, but

if you sense this might be hazardous in the dark, you could make a removable floor panel to cover the gap when you're inside. The door is built from a 75 x 50mm timber frame with cladding to match the walls. Strong hinges and a good-quality lock are recommended both for security and durability.

A plush interior

Power and lighting requirements are a personal choice. Many observers use portable batteries for powering mounts and red torches for lighting. However, we opted for mains power and chose to install two dimmable red lights, two white lights for maintenance work and a pair of mains sockets so we could use a computer. The power comes from the house via an armoured cable running in a deep trench and is protected by a residual current device (RCD) circuit breaker. All the electrical work should of course be carried out by a registered electrician. You might also consider installing network cabling so you can use the internet in your observatory.

Once the services were installed, we painted the inside of our dome with a wood preservative, followed by a matt black emulsion. The interior woodwork was given a gloss varnish. Then we laid a tongue-and-groove wooden floor, which is nailed to the joists. If you expect to lift your floor to make future changes, then straight-sided boards fixed with screws may be preferable. We lined our walls with thin (3mm) panels of MDF. You don't need to insulate the walls, but lining them does make it easier to pin up charts and photos. A pale wall colour helps you find your way around when the lights are dimmed.

Finally, we added some useful furniture. Space dictates what is possible, but a small desk is good for your laptop, eyepieces and charts, and a stool is welcome for resting your legs. If you have a tall mount you may also wish to make some moveable steps to reach the eyepiece. Most of the furniture spends its time on the northern side of our dome, but we recommend not fixing anything permanently as you will inevitably want to move it at some point.

Hopefully you'll soon be observing from your very own dome. You may opt for a different design, but many of the issues will be similar. If you have made the effort, your enjoyment of the night sky will be even more satisfying.

TURN THE PAGE FOR MORE ▶

STEP-BY-STEP

Step 1

The shutter panels overlap the opening like a lid. They could be lifted on and off, but small castors fitted to the edges run smoothly over the curved surface of the dome so the main section can simply roll back. We painted the inside matte black.

Step 2

Fit a pair of pulleys near to the top of the shutter opening. Use strong nylon cord (4–6mm thick) to open and close the shutter and a cleat to tie the cord off, securing the panel when closed. We also fitted sliding bolts to secure the shutter.

Step 3

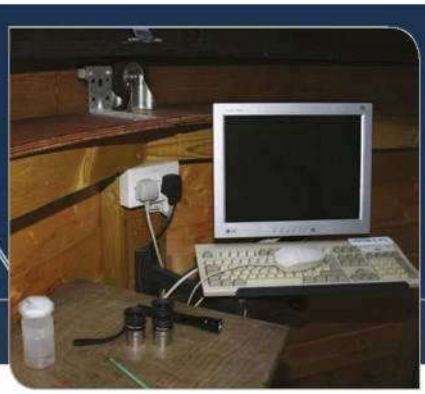
As well as a good-quality door lock and bolts, we used long bent hinges to make the observatory secure. These flap down from the dome and prevent it lifting or being lifted. To rotate the dome, simply flip them back up.

Step 4

Lights, power sockets and communications cables will enhance your experience. We selected tough bulkhead lights to resist knocks. Some have dimmable red bulbs to preserve night vision. A qualified electrician should carry out this work.

Step 5

Once all the painting and wiring has been done, you can fit the wooden floor. Nailing the boards in place is fun and a sign that you're nearing the end of the job. If you want, you can line the walls with thin wooden panels.



Step 6

Small items of furniture and equipment (depending on requirements) can now be installed. Make sure you leave enough room to operate your telescope. It's wise not to permanently fix anything, as you'll inevitably need to move it around.

▲ The observatory's roof shutter is made of two parts: the upper one rolls back, while the lower one lifts out

► Once the observatory is fully constructed and installed, you'll be able to begin your stargazing sessions within a matter of minutes

▼ The pier is bolted into a block of concrete separated from the floor, meaning you can walk around it without creating vibrations

ALL PICTURES: MARK PARRISH

COST ESTIMATES FOR THE OBSERVATORY'S CONSTRUCTION

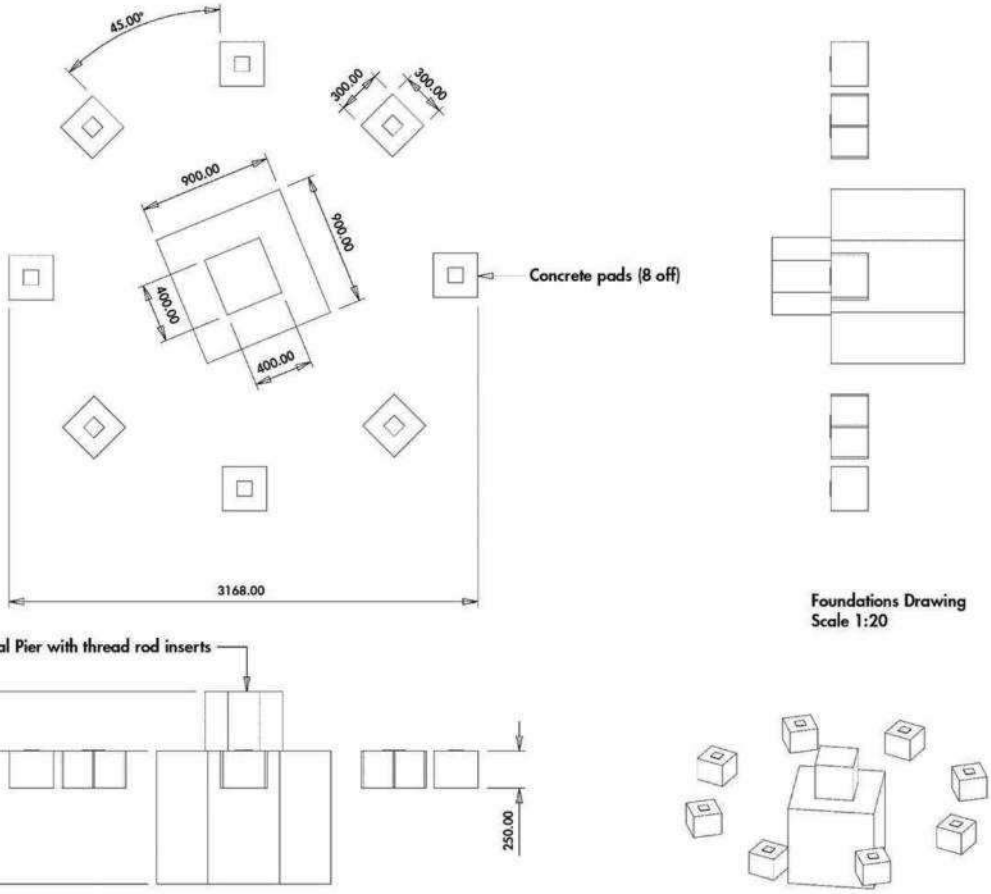
ITEM	DETAILS	AMOUNT	COST PER UNIT (APPROX)	COST
CEMENT	25KG BAGS	12 BAGS	£6.80	£81.60
BALLAST	1M^3 BULK BAGS	1.5 BAGS	£40	£60
WALL POSTS	100x100MM TREATED SOFTWOOD	8 POSTS	£15.18 PER POST	£121.44
CLADDING BATTENS	50x50MM TREATED SOFTWOOD	24 METRES	£2.50 PER M	£60
JOIST SUPPORT BEAMS	100x50MM TREATED SOFTWOOD	1 METRE	£3.40 PER M	£3.40
TOP BRACING	100x22MM TREATED SOFTWOOD	10 METRES	£2.30 PER M	£23
HARDWOOD FOR BLOCKS	100x30MM HARDWOOD	1.8 METRES	£10.40 PER M	£20.80
FLOOR JOISTS	150x50MM TREATED SOFTWOOD	30 METRES	£4.78 PER M	£143.40
FLOOR BOARDS	140x18MM TONGUE & GROOVE	50 METRES	£2.70 PER M	£135
WALL CLADDING	150x15MM FEATHERED-EDGE TREATED	110 METRES	£0.98 PER M	£107.80
WALL RING	2,440x1,220x18MM PLYWOOD	1.5 SHEETS	£34	£51
DOME RING	2,440x1,220x12MM PLYWOOD	3 SHEETS	£25	£75
DOME SKIRT	2,440x1,220x3MM PLYWOOD	1 SHEET	£13.80	£13.80
DOME RIBS	2,440x1,220x12MM PLYWOOD	4 SHEETS	£25	£100
DOME CLADDING	2,440x1,220x3.6MM HARDBOARD	7 SHEETS	£6.80	£47.60
SHUTTER CLADDING	2,440x1,220x3.6MM PLYWOOD	1 SHEET	£13.80	£13.80
RESIN	3 LAYERS, EACH AROUND 7.2KG	1 20KG DRUM	£84	£84
CHOPPED STRAND MAT	16M^2 OF 450GM	16M^2	£2.30 PER M^2	£36.80
GEL COAT	1 LAYER OF 3.5KG	1 5KG DRUM	£30	£30
CATALYST	500G ADDED TO RESIN & GEL COAT	1 1KG BOTTLE	£9.60	£9.60
CASTORS	100MM FIXED CASTORS	8 CASTORS	£5.47	£43.76
SKIRT CASTORS	50MM FIXED CASTORS	8 CASTORS	£3.40	£27.20
SHUTTER CASTORS	30MM FIXED CASTORS	8 CASTORS	£1.87	£14.96
				TOTAL: £1,303.10

ADD COST OF SUNDRIES SUCH AS SCREWS, NAILS, PAINT, WOODSTAIN AND ELECTRICS DEPENDING ON REQUIREMENTS

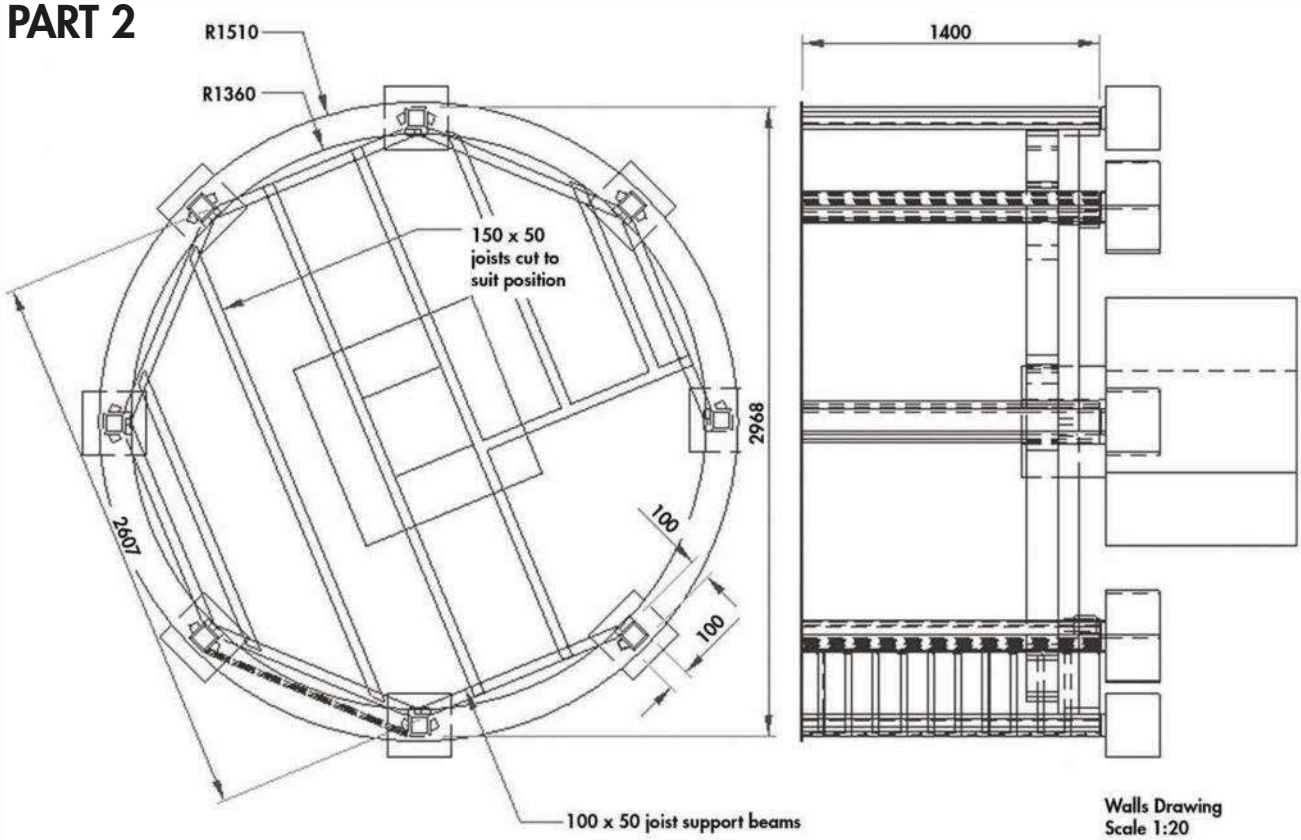
TURN THE PAGE FOR PLANS ▶

Plans and measurements

PART 1

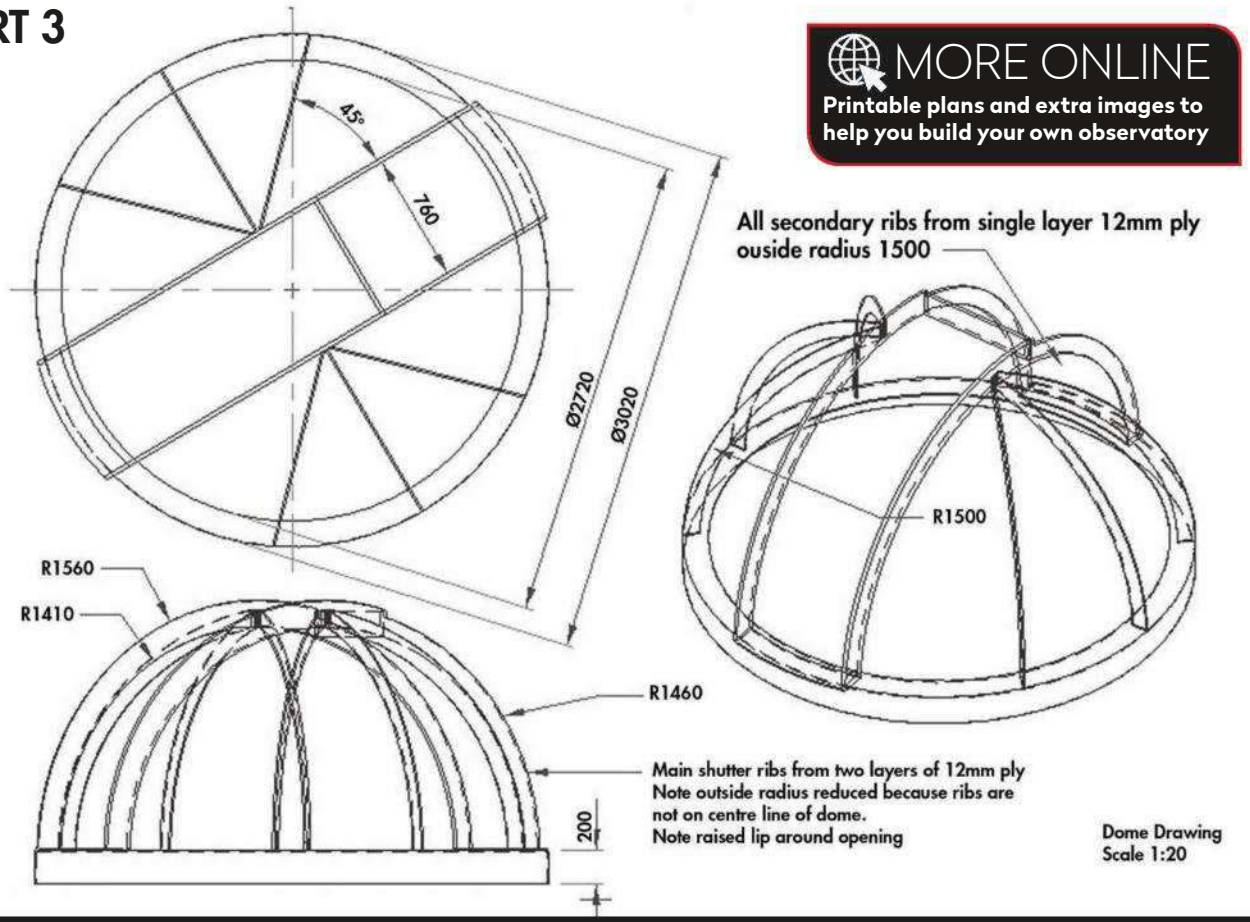


PART 2



ALL PICTURES: MARK PARRISH

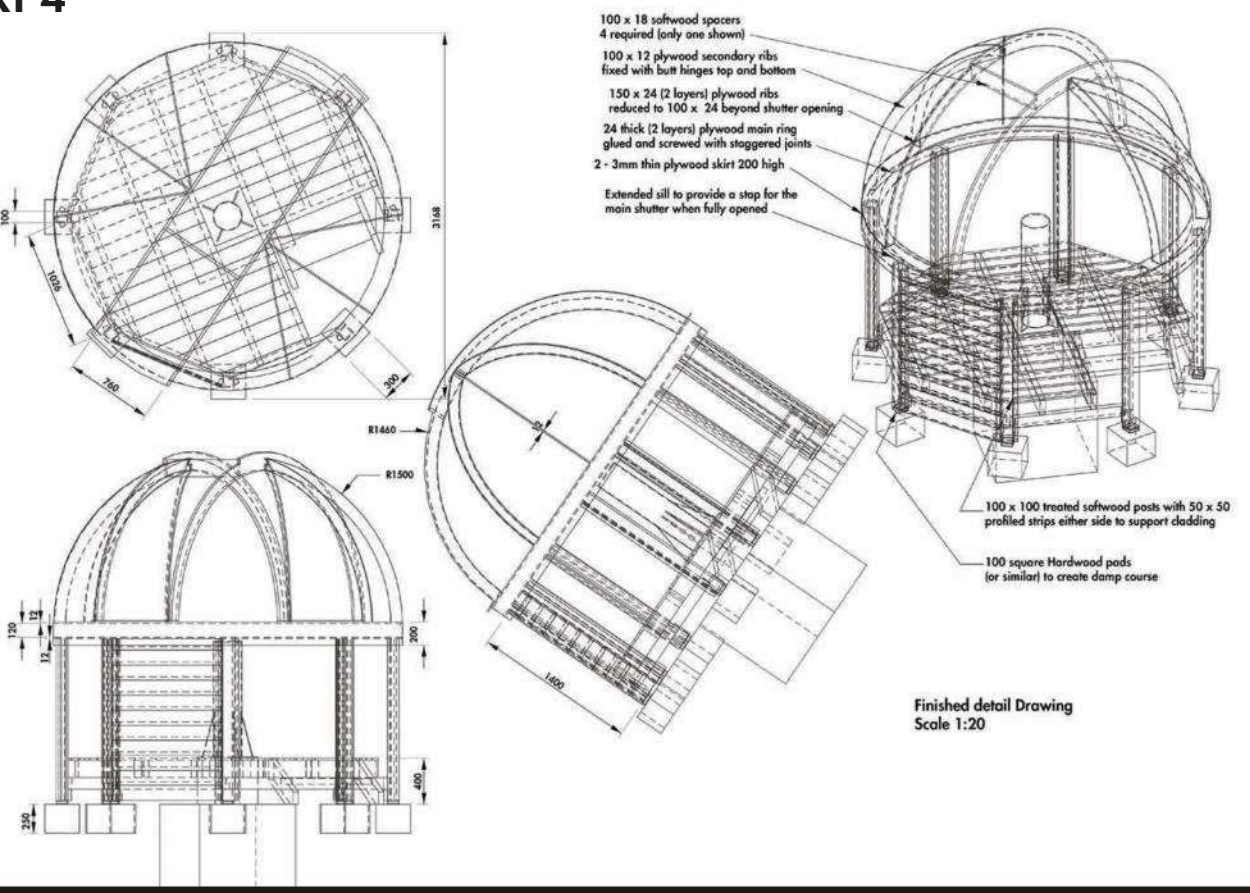
PART 3



MORE ONLINE

Printable plans and extra images to help you build your own observatory

PART 4


100 x 18 softwood spacers
4 required (only one shown)
100 x 12 plywood secondary ribs
fixed with butt hinges top and bottom
150 x 24 (2 layers) plywood ribs
reduced to 100 x 24 beyond shutter opening
24 thick (2 layers) plywood main ring
glued and screwed with staggered joints
2 - 3mm thin plywood skirt 200 high
Extended sill to provide a stop for the
main shutter when fully opened
100 x 100 treated softwood posts with 50 x 50
profiled strips either side to support cladding
100 square Hardwood pads
(or similar) to create damp course
R1460
R1500
Finished detail Drawing
Scale 1:20

▲ Domed observatories need careful watching to keep the roof aperture in line with the scope

Automate your observatory Part 1

Get your home dome rotating with motorised precision

By Steve Richards

The convenience of a permanent observatory cannot be overstated: once you have one, it only takes minutes to be out and observing when the sky conditions are good. If you're a deep-sky astrophotographer in particular, you will benefit enormously from the greatly reduced set-up times as all your photographic equipment can be left in place, your mount is already polar aligned and your equipment balanced. All you need to do is switch it on and perhaps perform a simple star alignment at the start of the session. Automating the rotation of the dome, which is the subject of this article, is the icing on the cake.

Many astrophotographers start an imaging sequence and then retire indoors to let their setup run by itself. This works very well if you have an observatory with a roll-off roof, but a conventional domed observatory has to rotate precisely so that the telescope continues to point through the roof aperture. This means that you have to step outside every 20 minutes or so to nudge the dome round a little. Completing this project will fully automate this process.

There are various homebrew solutions to driving the dome in azimuth that require engineering, electronics and software skills beyond the scope of this article. Instead, we opted for an off-the-shelf package designed specifically for our Pulsar observatory; other dome makers have drive systems tailored for their particular dome design. This well-proven azimuth drive was the start point for a fully automated imaging observatory.

All azimuth drive systems require a motor drive using either a friction drive or a cog drive of some kind, a control box, a position sensor (encoder), a home sensor and control software. The system detailed here uses a friction drive and the popular LesveDome ASCOM drive software.

Attach the three units

The motor housing, control box and encoder are attached to the wall of the observatory by carefully marking and drilling suitable holes, taking care not to crack the gel coat on the outside. Drill small pilot holes from inside first, then drill the main holes from the outside with the drill running in reverse to grind, rather than cut, the hole through. Attach the three units using the supplied stainless steel nuts, Allen bolts and washers. Decide where you would like the dome to 'park' and then move it manually to this position – you can then mark the position of the home actuating cam on the dome flange

TOOLS AND MATERIALS

Tools
Drill, drill bits, marker pen, masking tape, tape measure, metric Allen keys and metric spanners.

Drive gear
A Pulsar rotation drive system comprising USB control box, motor drive housing, encoder unit, 12V power supply unit, homing cam and all fastenings.

Hardware
A suitable computer running Windows (XP upwards) with a spare USB port.

Software
You will need to have installed the latest ASCOM platform (free; http://ascom-standards.org), Microsoft.NET Framework 4.0 or later (free; www.microsoft.com/net) and the LesveDome control software (paid; www.dppobservatory. net/downloads/downloads.php).

ALL PICTURES: STEVE RICHARDS

▲ **Once installed, you won't have to keep popping out to move your dome while imaging**

where it centres over the home sensor built into the motor housing.

For long-exposure astrophotography, an equatorial mount is required and in most setups this takes the form of a German equatorial mount. These popular mounts follow the apparent movement of the stars in a smooth arc: ideal for imaging, but through the course of the imaging session, the telescope starts on the west side of the pier pointing east and ends up on the east side of the pier pointing west.

This non-linear pointing has to be accounted for to ensure that the telescope points through the dome's aperture at all times, requiring some complex mathematics. It is the job of the dome control software to do this for you. However, to do this correctly, the software must know exactly where the telescope is mounted in relation to the centre of the dome, so your first task is to make some careful measurements to obtain the dimensions required. Using the spreadsheet available on the bonus content section of our website will make it easier to get all the dimensions correct and ready for insertion into your software.

Once done, install the ASCOM software and enter the offsets from your spreadsheet – ensuring the correct signs (positive or negative) – into your choice of control software. We used MaxIm DL and POTH (Plain Old Telescope Handset), but another popular choice is Sequence Generator Pro. Then, with the measurements uploaded, your telescope and dome aperture will be in sync.

MORE ONLINE

Use our spreadsheet to simplify the alignment process in this project

TURN THE PAGE FOR PART 2 ▶

STEP-BY-STEP

Step 1

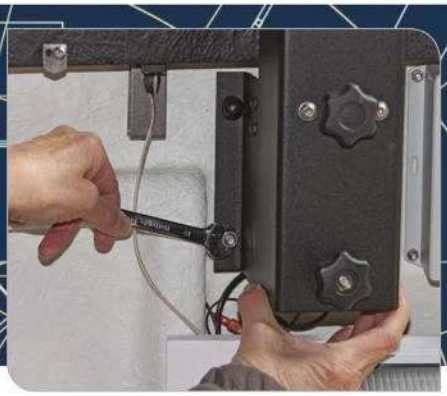
Position the control module and mark the position of the four retaining bolts. Then place the drive unit to the left of the control box leaving a 10mm clearance between the drive unit and the lower dome and mark the position of the four retaining bolts.

Step 2

Place the encoder module in position behind the dome flange and mark the position of the mounting bolts on the observatory wall. Drill small pilot holes through each of the marked hole positions using a 2mm drill with the drill turning in a clockwise direction.

Step 3

Carefully drill 8mm holes for the control panel, from the outside, using the pilot holes as a guide. Repeat the process for the motor drive unit and the encoder module using a 6mm drill. Run your drill in reverse to prevent the gloss gel coat from cracking.

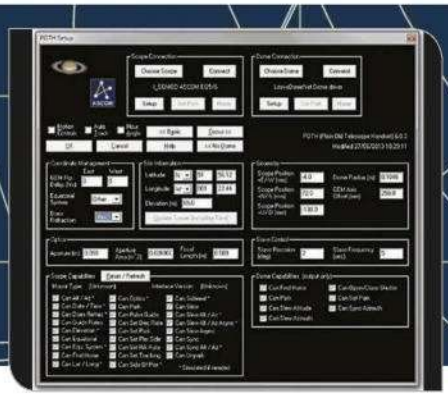


Step 4

Attach the three modules to the observatory wall with nuts, bolts and washers, making sure that both the drive unit and encoder are perfectly vertical. Determine the dome's 'home' position, mark and drill mounting holes for the cam and attach it to the dome flange.

Step 5

Measure the position of the pier centre and all mount dimensions shown in our bonus content spreadsheet. These figures must be accurate so the drive software can calculate exactly where to move the dome aperture to match the pointing of the telescope.



Step 6

Install the ASCOM platform and LesveDome software on your observatory computer. Run LesveDome and enter the set-up parameters supplied by Pulsar Observatories. Make POTH your default dome driver and enter the figures from the spreadsheet into the Geometry section.

▲ Automating the dome's motion and aperture is the first step to an autonomous observatory

Automate your observatory Part 2

Open your dome's aperture at the touch of a button

By Steve Richards

In Part 1 of this build, we showed you how to automate the rotation of an observatory dome. Now we are going to take things a step further and automate the aperture opening.

All amateur domed observatories have a sliding lid that reveals a vertical rectangular aperture, giving access to the whole sky, including the zenith. This lid is normally operated manually, but automating the process has advantages – for example, you could add a detector that closes the aperture if it starts to rain. This kind of automation also opens the door to the exciting prospect of remote or even autonomous operation.

The curved profile of these apertures makes motorising them a little problematic, but the chain drive system described here is both elegant and secure. Because the dome must be free to rotate, it cannot be electrically connected to the rest of the observatory, so the aperture motor drive requires its own power supply. In the case of the Pulsar system we are using, this comprises a small, motorcycle-style 12V lead acid battery, along with a solar panel to keep the battery topped up and ready for action.

For the same reason, open and close commands from the main controller must be sent over a wireless link. In this project, a simple two-channel 433.92MHz radio frequency link connects to the main controller we installed in Part 1. A more recent version launched by Pulsar uses a bi-directional Bluetooth link.

Begin by removing the aperture lid to gain easy access for fitting the three guides and top return roller for the chain. It is important that these are placed approximately equidistant from one another, from the drive cog built into the motor housing at the bottom, and from the roller at the top. This ensures that the chain follows the contour of the dome aperture as closely as possible.

Connecting the chain

The position of the top roller is at the top edge of the aperture. Place the motor housing onto the flat vertical panel under the aperture opening, ensuring that the top of it is 10mm lower than the bottom of the aperture opening. Mark the position of the cog by placing a piece of masking tape aligned with it on the dome, in line with the left-hand side of the aperture as seen from inside the dome.

Place each of the three side-chain brackets over the dome edge in turn and position them equidistantly spaced. File the glass-fibre edge if necessary using a metal file and sandpaper until they are a neat, firm fit. Mark then drill a 2mm pilot hole clockwise through the fixing holes from the gel coat side (the outside) and then drill 6mm holes. Do this with the drill running anticlockwise, so you

TOOLS AND MATERIALS

Components
The Pulsar Shutter Drive system comprising an RF controlled motor drive housing, limit switches, 12V battery, solar panel, nylon chain, roller, chain guides and all fastenings

Tools
A variable speed drill with 2mm, 6mm and 8mm bits, a set of metric Allen keys, flathead and crosshead screwdriver, a set of metric spanners and a metal file.

Sundries
Sandpaper, a marker pen, masking tape and a tape measure.

ALL PICTURES: STEVE RICHARDS

grind a hole rather than drill it, to avoid damaging the gel coat finish.

Bolt the three brackets in place using 6mm nuts and bolts and then loosely loop the nylon chain through each guide. This will help you to assess whether or not the guides are in perfect alignment with one another. If necessary, you can pack them with washers until the alignment is spot on.

Again, using the nylon chain as a guide, position the top roller in perfect alignment with the side-chain brackets, mark the mounting holes and drill them in the same manner as for the chain brackets. Attach with bolts and check that the roller is carefully aligned and horizontal. As before, you can pack with washers to ensure correct alignment. Reposition the drive motor housing again, align the cog accurately with the nylon chain, then mark and drill the mounting holes as before, but using an 8mm drill bit. Attach it with 8mm nuts and bolts.

Mark, drill and attach the two limit switches and single limit switch actuator, then mark, drill and attach the solar panel to the outside. Finally, connect the top limit switch, battery and solar panel to the motor housing and complete the chain around the drive cog.

▲ A mounted solar panel will keep your 12V battery charged and ready for use

"Because the dome must be free to rotate, it cannot be electrically connected to the rest of the observatory"

STEP-BY-STEP

Step 1

From inside the dome, place the motor housing onto the flat vertical panel under the aperture opening so that the top is 10mm lower than the aperture opening. Mark the approximate position of the drive cog in relation to the aperture wall with masking tape.

Step 2

Remove the shutter and mark the position of the mounting holes for the top bracket and each of the three side-chain brackets. Ensure they are equidistant from one another and from the drive cog position. Drill 6mm holes and mount the brackets in position.

Step 3

Lace the chain through the brackets, bringing the ends to the drive cog position. Ensure that all the brackets are aligned with one another. Reposition the motor housing again, aligning the cog accurately with the chain. Mark and drill 8mm holes and attach the housing.

Step 4

Mark, drill and attach the top and bottom limit switches to the dome. Mark, drill and attach the limit switch actuator to the lid and refit the lid. Run the switch cable from the top limit switch behind the chain brackets and down to the aperture bottom.

Step 5

Close the shutter, allowing a 25mm overlap at the front of the dome, and position the chain against the shutter right next to the top bracket. Mark and drill a 6mm hole through the shutter and attach the chain to the shutter with a 6mm bolt.

Step 6

Loop the chain around the drive cog and complete the chain with the final link. Mark and drill holes for the solar panel and attach it with the supplied bolts. Attach the lead from the top limit switch to the control board and connect the battery.

MOUNTS

Freedom of movement and rock-solid stability are the two seemingly mutually exclusive things that a good mount must provide. Here, we'll show you how to build different types that deliver this crucial combination

BACKGROUND IMAGE: ISTOCK, MARK PARRISH X 2, STEVE RICHARDS

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Make a low-cost wooden tripod

By Mark Parrish

Construct your own portable alternative to a solid pier or home observatory

Most astronomers would love to have a permanent observing setup in their garden and an observatory or a solid pier is often the dream solution. But of course, neither of those options is always possible, or practical. There might be nearby trees or buildings that mean you have to shift your setup around your garden to view different parts of the sky, or you may not be able to make permanent changes to your property. Whatever limitations you face, the result is that you're obliged to use a moveable tripod, which brings its own issues. Taking your tripod indoors after each session means losing your polar alignment, but leaving an expensive piece of equipment outside might attract the attention of thieves. The solution is an inexpensive, stable tripod that can be left in place or moved around as needed, and that's what we're showing you how to make here.

The timber you'll need can be readily acquired from a local builders' merchant. We chose 'prepared' (planed) timber because it's nicer to handle and looks attractive, but you could use equivalent rough-sawn wood to reduce the cost further. Each leg frame is bolted together and the three are joined with hinges, which means you don't need to have any special skills to assemble the main parts.

The tripod is immensely strong and has plenty of mass, which helps to provide a solid platform upon which to fix your mount. The tripod we built is 1,065mm (3.5ft) tall but you can alter the design of the central pier to make it taller if your telescope is a long refractor or shorter if it's a big Newtonian. We used a dark brown preservative wood stain, but there are many colours available, so you could camouflage your tripod to blend in with the bushes or match any other garden furniture and features.

TOOLS AND MATERIALS

Tools
Hand saw, jigsaw or chop saw, drill and bits.

Materials
Two 2.4m (8ft) lengths of 98 x 38mm construction timber, four 2.4m (8ft) lengths of 63 x 38mm construction timber, 1/8th of a sheet of 18mm plywood or similar, plus a few offcuts of plywood.

Sundries
Nine M10x150mm coach bolts with nuts and washers, three pairs of 75mm butt hinges and screws. A few 4-inch and 2-inch woodscrews, plus a pair of M6 x 60 bolts with wingnuts.

Finish
Approxiomately 0.5l of preservative wood stain.

The tripod can be left outside and polar aligned for as long as is needed

ALL PICTURES: MARK PARRISH

The top of the tripod and the mount fixing are made from hexagonal plywood plates. If you can't remember your geometry lessons from school you can download a template from www.skyatnightmagazine.com/bonuscontent. It's best to cut the plates simultaneously so that each one ends up the same shape. If you mark one edge of the stack you can realign them easily even if they aren't perfectly symmetrical.

Plating up

Your telescope mount will be bolted to its own removable hexagonal top plate, which fits precisely into the fixed top tray on the tripod. This means you can lift off the whole assembly after an observing session and then replace it on a subsequent evening, maintaining your polar alignment. We drilled two holes through our top plates and used a couple of small bolts with wingnuts to hold them together when the mount is lifted on, so there's no danger of the scope being knocked off. You could also use a G clamp for this.

Adapting the removable top plate to suit your mount may require a bit of careful measuring and cutting. Having examined a multitude of EQ mounts from various manufacturers, however, it seems that most can be made to fit simply by cutting a large, round hole (approximately 60mm in diameter) in the upper, thick layer of plywood and a smaller 10mm hole in a thinner layer that's subsequently glued beneath. Many manufacturers sell 'pier top adaptors' for just this kind of project and they're worth investigating if you prefer to keep things simple.

If you need a stable, temporary base on which to mount your equipment you should give this project a try. If you have a number of different mounts you could make a separate top plate for each one, so that swapping them around is a cinch. Alternatively, you could make a few different tripods and position them in the optimum areas of your garden for different sections of the sky and switch between them during a night of observing.

MORE ONLINE
Download cutting templates for all of the mount's parts

STEP-BY-STEP

Step 1

After carefully marking out the parts, use a saw to cut them to size. You can download templates from the bonus content online to help you get the angles right. A chop saw could save you some time here. Check that similar pieces match once they're cut.

Step 2

Drill the 10mm holes in one example of each part. Use this to transfer markings to the corresponding parts. You can line up the parts with the 'master' on top then put a bolt in the hole and strike it with a hammer to mark the one below with a dent.

Step 3

Once all the timber is cut, sand any rough edges and check everything fits together. If the holes are tight you can wiggle the drill bit through them or re-drill them using a 10.5mm bit. Now is a good time to paint the wood with preservative stain.

Step 4

Bolt the three triangular leg frames together. Each short foot section should be fixed between the two leg struts with long woodscrews once you have aligned the other elements. Fix a pair of hinges to each frame then join all three frames to form the tripod.

Step 5

Mark out the plywood hexagons. Drill a centre hole in each and a second hole near one corner, then use small bolts or dowels to hold the layers together before cutting – this ensures replica hexagons. Screw one fixed top plate to the tripod and add plywood lips.

Step 6

Measure your mount. Cut a suitable hole in a removable top plate. Glue a block of hardwood or similar into a notch to form a pin for the alignment screws. Screw a second thin layer of ply (with a central hole for the fixing screw) to the underside.

Make a binocular mirror mount

MORE ONLINE
Cutting list and construction plans

A simple project to take the strain out of binocular astronomy

By Mark Parrish

Binoculars are invaluable tools for amateur astronomers, but for effective use they need to be held steady for long periods of time. This is both tiring and challenging, particularly if the binoculars are heavy. Aiming at celestial objects close to the horizon isn't too difficult, but point closer to the zenith and you may soon find yourself setting up sun loungers, or improvising methods for steadying or bracing yourself (see our tips on page 12).

Here we're going to build a table-top binocular mount with an adjustable mirror and pivoting base for hands-free observations. With this, you can simultaneously take notes, make sketches, or even share the view with companions. Best of all, at all times you look downward into the binoculars at a comfortable angle, so you never have to suffer that cricked neck feeling again. Our design uses stock-sized timber and requires only minimal woodworking skills. The type

ALL PICTURES: MARK PARRISH

▲ This table-top mount delivers steady and comfortable views – so no more neck ache

STEP-BY-STEP

Step 1

Print out the plans from our online bonus content and use these to mark out and cut the various pieces of timber to size. If you are lucky enough to have a timber merchant who can do this for you, all you need to do is cut the 45° angles with a handsaw.

Step 2

Clamp or tape the wood together to see where screw holes need to go. The triangular shape is inherently strong, so only one screw is needed at each joint. Countersink the holes so the screws sit flush with the surface. Slightly stagger opposing screws so they don't clash.

Step 3

Mark out and drill the pivot holes. Note that the pivot bolts for the mirror sides should be glued in with epoxy resin so that they don't turn in their holes. After drilling, carefully sand all the parts so they are smooth and fit together nicely.

of mirror you need is a first- or front-surface mirror. This means that the reflective surface is on the outside face of the glass, rather than underneath it as in a typical mirror of the type you might have in your bathroom. The reason is that front-surface mirrors produce a single clean reflection, whereas the bathroom type produces a second 'ghost' image from the outer layer of the glass.

High-quality mirror

The mirror surface is delicate, so care is needed when handling it; we'd also recommend a cover to protect it and prevent dust building up when not in use. We sourced our mirror from Vacuum Coatings (www.scientificmirrors.co.uk); other stockists include Knight Optical (www.knightoptical.com).

The quality of the mirror surface is important – ours is fine for binoculars in the 50–70mm range and we have designed the mount to suit binoculars of this size. Larger (say 80–100mm) binoculars could be accommodated with a scaled-up design, but the quality of the mirror and subsequent cost may become the limiting factor – it is worth discussing your requirements with the mirror supplier if in doubt.

All of the timber frame parts are made from 36 x 18mm wood, a common size found in DIY stores. We were lucky to obtain some nice hardwood, but good-quality softwood is fine. The round base and the mirror base are made from an offcut of 12mm plywood, but a similar thickness of MDF would be fine. The pivots for the mirror and base are M8 bolts with nuts and washers. A wingnut is used to tighten and loosen the mirror during repositioning.

The special low-friction base is just an old vinyl LP record (Holst's *The Planets* might perhaps be appropriate) stuck to a plywood disc, with some felt pads under the frame gliding around above it. Alternatively, you could simply move the frame about on a smooth surface or improvise a tripod mounting. If you do take the tripod route, use the pivot hole position to determine the centre of gravity or balance point.

The mount is delightfully simple to use: just sit it on a suitable table, turn it so it is facing the area of the night sky you wish to observe, and then rotate the mirror to bring the view into position. We found it was quite easy to look into the mirror along the top of the binoculars to achieve a close enough aim. You do get a reversed and upside-down view of the sky, which takes a little getting used to, but that is more than made up for by the steady, comfortable views and the resulting ability to discern faint detail.

▲ Observing hands-free means you'll have more freedom to make notes and sketches

TOOLS AND MATERIALS

Materials

12mm plywood for mirror base and round base; approximately 2.7m of 36 x 18mm softwood or hardwood; front-surface mirror, approx. 200 x 15mm.

Sundries

No 8 x 1.25-inch brass woodscrews, three M8 x 60mm countersunk bolts with wingnuts and washers, a 12-inch vinyl record, felt furniture pads, rubber feet for base.

Tools

Tenon saw, coping saw, drill with bits for screws (8mm for pivots, 4.5mm for clearance, 2.5mm for pilot holes) and a countersink bit, sandpaper, ruler, pencil, screwdriver.

Finish

Exterior gloss paint or varnish, or an oil or wax finish, depending on the wood and the effect required.

Step 4

Drill a 2.5mm pilot hole for each remaining screw – this makes it easier to screw in and prevents splitting. Add some PVA wood glue to the joint before tightening. Note the temporary wood spacers in the picture above to keep the mirror fork base horizontal.

Step 5

Test fit your binoculars. We made our mounting plate from a strip of brass screwed to the binocular mount block. This needs to be positioned so the front of the binoculars is approximately 110mm from the mirror face, ensuring a clear view of the zenith.

Step 6

Finish the disassembled wooden parts with paint or varnish. The mirror fork arms are not glued, so the mirror assembly can be removed. Use four dabs of mastic to glue the mirror to the base. Add a 12-inch vinyl record and felt pads to complete the pivot.

BIG BUILD

Make a binocular PARALLELOGRAM MOUNT

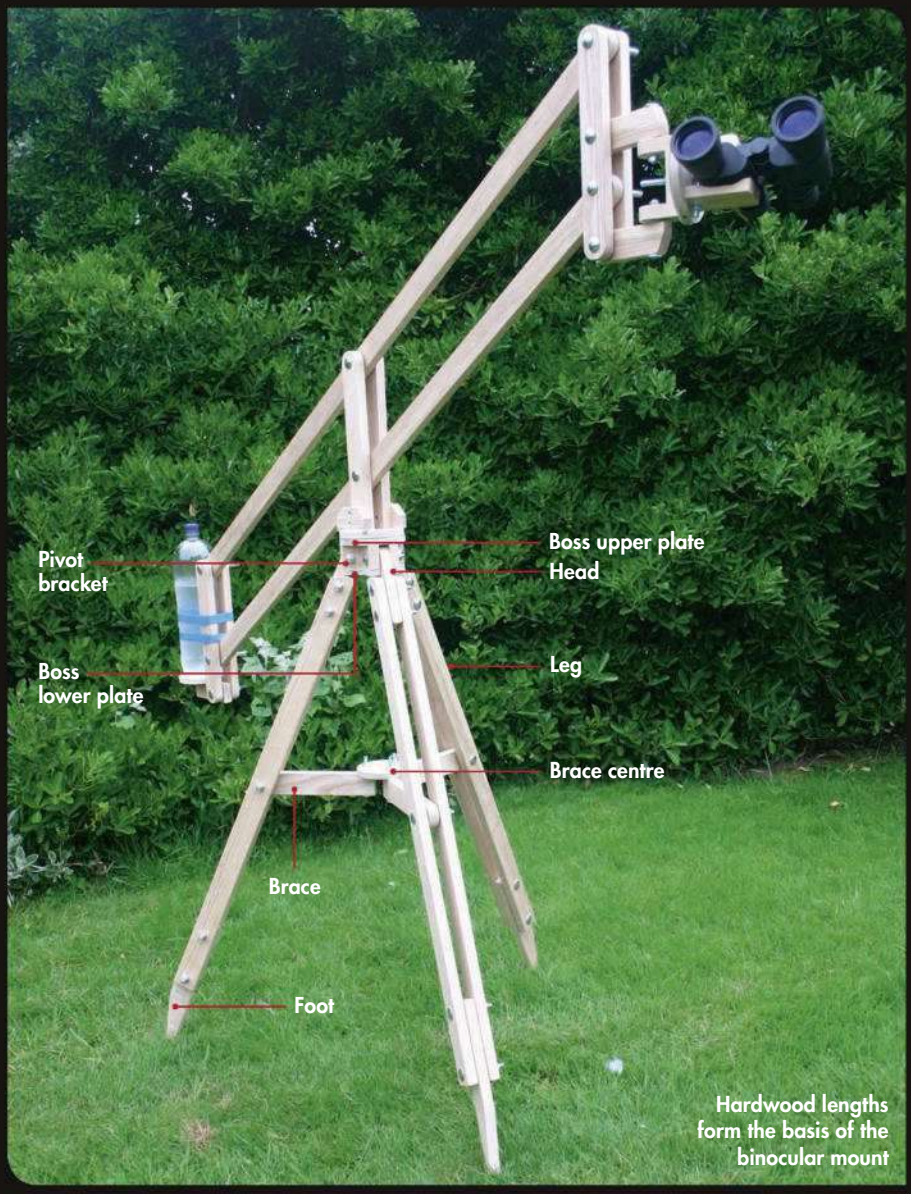
Part 1

By Mark Parrish

Banish binocular wobbles and observe in comfort with this attractive wooden mount

Binoculars are deservedly popular for their convenience and wide-field views of the night sky, but even a pair of 10x50s can make your arms and neck ache after a while, especially if your target is high in the sky. A parallelogram mount is an established solution to the 'wobbles', allowing you to sit or stand in comfort with the binoculars supported separately – you can even line them up with your target and then invite someone else to look through them.

In the first part of this build we'll make the sturdy wooden tripod using stock-sized timber. In the second part we'll tackle the parallelogram mount that sits on top. There are several designs around for DIY mounts, but we have carefully designed ours so it can be made with basic tools and readily available materials. All of the joints and pivots are made in the same way, so it is possible to use a few simple jigs if you have access to some power tools. Because we use the same fixings throughout – M8 bolts, penny washers and nuts – they can be bought in bulk, which helps to keep the cost of the project realistic.



Hardwood lengths form the basis of the binocular mount

ALL PICTURES: MARK PARRISH

Hardwood and ply

The main timber parts are cut from strips of hardwood. We used ash, but any good-quality, straight hardwood would be suitable. You could even use softwood if you're on a tight budget, but make sure it is straight, and free from knots and splits.

The discs that form the head of the tripod and the brace centre are cut from 12mm furniture-quality plywood, which is stable and nice to work with. You'll find a list of parts you'll need on our website, including a cutting list of all the wooden parts, so you can ask a timber merchant to prepare a lot of the pieces for you.

Our tripod can be folded flat by unscrewing two of the braces from their central disc. These fold back into the legs, which in turn fold together. We recommend adjusting the length of the braces and drilling the central disc holes in situ, as this will allow you to compensate for slight variations in the size of other parts during manufacture.

The legs are a fixed length, but if you are likely to encounter sloping ground

TOOLS AND MATERIALS

Finish
For a nice moisture-resistant finish, apply some gloss varnish or wax polish – this will help to prolong the tripod's life.

Sundries
For the tripod and mount you'll need 34 M8 x 75mm bolts, 56 M8 penny washers, 27 nylon washers, 34 regular washers, 31 nyloc nuts and three wing nuts.

Tools
You will need a fret or coping saw (or an electric equivalent), a drill and suitable bits, a plane, a file, sandpaper, a ruler, a compass, a pencil and some wood glue.

Wood
About 8m of 44 x 18mm hardwood for the tripod (plus another 6m for the mount). Most of the other parts can be made from a small sheet of 12mm plywood. See the plans and cutting list online.

you may elect to turn the fixing holes in the feet into slots – this will enable you to level the mount, should you need to. Using penny washers and nylon washers between all wood-on-wood contact points means you can tighten the nyloc nuts just enough to ensure smooth pivots but eliminate wobbly joints.

You might need to make a few small adjustments early in the life of the tripod if you notice it becoming loose – particularly if this happens where the legs meet the top platform. If you find that any joints are persistently 'sticky', upgrade the washers to PTFE ones, which are renowned for their low friction.

For a high-quality and durable finish, we recommend applying several coats of an exterior varnish, rubbed down, or perhaps a coat or two of wax polish. This will maintain the appearance, prolong the life and ensure the smooth operation of your tripod.

MORE ONLINE
Find templates and a cutting list

TURN THE PAGE FOR PART 2 ▶

STEP-BY-STEP

Step 1
If you're lucky, a timber merchant will be able to do most of the cutting for you. Use a saw to shape the feet and make adjustments to the brace lengths as needed. Mark the hole positions carefully, following the plans on our website.

Step 2
Carefully mark out the plywood parts. Use our printable template to mark the slightly tricky lower section for the tripod top. Carefully cut out the sections using a coping saw or (even better) an electric fret saw. Smooth the edges with sandpaper.

Step 3
Drill the holes for the M8 bolts. It is a good idea to tape similar parts together and drill them all at the same time – this will ensure good alignment. If you are using a pillar drill, you could try making a simple jig to keep the holes central.

Step 4
Use a disc-shaped template to mark out the rounded ends of the upper leg sections or 'heads' – though there are only three, there'll be lots on the parallelogram mount in part two. Saw and sand to the correct shape. Plane the corners and smooth all parts.

Step 5
Temporarily bolt the leg tops and pivot brackets together before gluing the tripod top assembly together. This ensures that the gap between pivots and alignment is correct. Use a small off-cut of dowel to align the centres of the top and bottom plates.

Step 6
Before assembling the tripod, give all of the parts a couple of coats of varnish or finishing wax, which should help with the friction at the joints. Once assembled, you will need to adjust the nyloc nuts to get smooth movement without looseness.

BIG BUILD

Make a binocular PARALLELOGRAM MOUNT

By Mark Parrish

With the tripod built, we turn to constructing the mount

Part 2

This tripod and mount will take the strain out of those long binocular sessions

In the second part of this project we'll cover how to put together the binocular mount. In part one, we explained how to build the wooden tripod the mount sits on, although with a little ingenuity it's possible to adapt the mount to fit an existing tripod, if you have one. You'll find plans and a parts list for the mount on our website, so you can ask your local timber merchant to prepare a lot of the pieces for you.

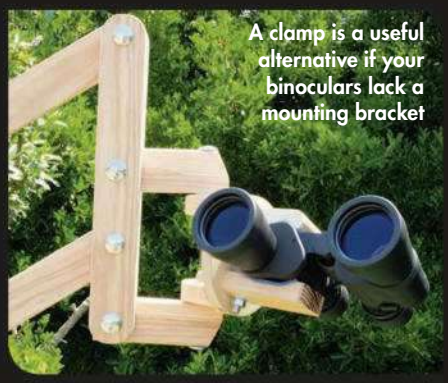
The articulated mount is designed to hold a small-to-medium pair of binoculars (typically 10x50 size) in a convenient position for either standing or seated observing. The parallelogram design is well-established, but instead of metal counterweights, this one uses a two-litre plastic bottle. The benefit of this is its flexibility: as a litre of water weighs 1kg, it's easy to top up the bottle to suit your optics. Once you have the right balance you can mark the bottle so it can be quickly refilled, making the system very portable. We used a loosely fitted cable tie to hold the bottle on the mount, but if your binoculars weigh more you could improvise a double-bottle solution.

All the joints and pivots are made in the same way as those on our tripod design, so it's possible to use a few simple jigs if you have your own power tools. The same fixings are used throughout (M8 bolts, washers and nuts), so they can be bought in bulk, which helps to keep costs down. We used hardwood for the main parts (ash, to match the tripod), but because 44 x 18mm is a common finished stock size, you should be able to find a suitable material at most timber merchants. The discs that form the bearings and bottle shelf are cut from 12mm furniture-quality plywood.

Nuts and bolts

Smooth movement is desirable in a mount like this. We used steel penny washers combined with nylon washers between all wood-to-wood surfaces. Nyloc nuts can be tightened just enough to ensure smooth pivots while eliminating any wobbles. If your bolts are a bit too tight to push through, you can re-drill the holes to 8.5mm, which makes assembly a little easier without sacrificing the integrity of the parallelogram.

To make a smooth bearing between the mount and the tripod, you can use an old CD. File out the central hole so it accepts a standard M8 washer – this helps to keep the CD centralised as the mount is rotated. We used a wing nut on the central bolt to hold the mount and tripod together, though a nyloc nut gives a more consistent pressure. The binocular pivot bearing,



A clamp is a useful alternative if your binoculars lack a mounting bracket

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Finish
Gloss varnish or finishing wax will give a good moisture-resistant, professional-looking finish and prolong the mount's life.

Sundries
For the mount you'll need 13 M8 x 75mm bolts, 20 M8 penny washers, 15 nylon washers, 12 nyloc nuts, one wing nut, a two-litre plastic bottle, PVA wood glue, some long cable ties and two old CDs.

Tools
A fret or coping saw (or electric version), centre punch, drill and bits, plane, file, screwdriver, spanner, ruler, pencil, wood glue.

Wood
About 6m of 44 x 18mm hardwood for the mount (plus 8m for the tripod – see Part 1). A small sheet of 12mm plywood can be used to make most of the other parts. See the plans and cutting list online.

which holds the fixing for the binoculars, is made smooth with a CD too, also with a washer fitted.

If your binoculars can accept a mounting bracket, you need only add a wooden block on the pivot bearing to screw on the appropriate bracket. Our binoculars don't have this feature so we made a simple clamp instead. One piece of wood forms the clamp's lower jaw and is fixed to the swivel head. Another piece of wood on a bolt then forms the upper jaw and can be tightened down on to the body of the binoculars. Slightly shaping the jaws and lining them with some soft foam (available from craft shops) provides good grip and helps reduce the chances of over-tightening the clamp.

Once you have built your mount you will wonder how you ever managed to use binoculars without it. You can sit in complete comfort for long periods of time, and can even use your free hands for sketching, or holding a drink… this is stargazing in luxury.

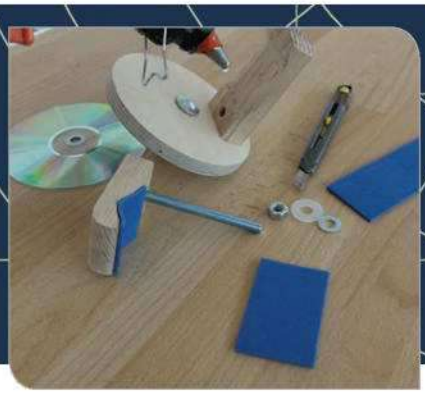
MORE ONLINE
Parts list and cutting templates

STEP-BY-STEP

Step 1
After cutting and shaping the parts for the mount's six vertical arms, use one 'master' piece to mark the holes on the remaining five. A dowel can be aligned to the holes on the master, then tap a centre punch to mark the other arms for drilling.

Step 2
Use some dowel (or pencils if you don't have any) to check the alignment of the holes on the centre pair of arms before gluing the centre supports in place. Add screws after the glue has dried to ensure the supports are strongly attached.

Step 3
Using countersunk woodscrews and glue to join the fixed parts together will make everything strong and rigid. Ensure the screws are sunk below the surface of the mount's 'foot' (which sits on the tripod) so it can turn smoothly on the CD bearing.



Step 4
If your binoculars have no bush for a fixing bracket, you can make a clamp from two wooden jaws lined with craft foam. The lower jaw fixes to the binocular pivot bearing and the upper jaw tightens down on it to grip your binoculars.

Step 5
Loosely bolt all the parts together before applying a finish. This gives you a chance to check everything fits well and moves smoothly. You may need to enlarge some holes if your bolts are too tight and making the mount's movements stiff.

Step 6
Before final assembly, give all of the wooden parts a couple of coats of varnish or finishing wax. Carefully adjust the nyloc nuts to get smooth and easy movement without looseness, especially the main CD bearings.

▲ A sturdy and level bird table (top removed) makes an ideal stand for the camera platform

Make a multi-camera stand

By Mark Parrish

Increase your chances of capturing a meteor spectacle with this DIY camera platform

Whether it's the Lyrids in April, the Perseid spectacle in August or Taurid's fireballs in the autumn, there are some nights where you just don't want to miss a thing. Wrapping up warmly and sitting under the stars is a wonderful way to enjoy the show, but a photographic record of even just one elusive trail can be a beautiful memento, as well as being of scientific interest.

This project is a simple mount that enables you to aim up to four DSLR cameras towards the sky. How many you choose to use, and their orientation, will depend on what you have available. The principle is to cover as much sky and take as many images as you can, in the hope of a bright trail appearing in one of the cameras' fields of view at just the right moment.

The DSLRs are mounted on hinged brackets pointing upwards towards the night sky. The hinges allow for individual cameras to be pivoted downwards during the imaging session in order to check the recorded images on their review screens,

"The principle is to cover as much sky and take as many images as you can in the hope of capturing a bright trail"

alter focus and exposure, and change batteries and memory cards. You may want to repurpose a bird table for the stand – they have a suitable tall post and a sturdy base so, as the birds won't be using it at night, you could remove the top for a few hours of meteor hunting. But if you don't have a bird table, don't worry. This mount can also be put on a table top or screwed onto a fence post, so it is quite versatile.

Four cameras?

There are lots of cheap, second-hand DSLR cameras on the market, making this a financially viable project to contemplate. A secondhand Canon EOS 300S is a suitable candidate and with its modest-sized sensor and lens at 18mm

TOOLS AND MATERIALS

Tools
Handsaw or equivalent, drill with bits to suit woodscrews, clamps or a vice, small hammer, screwdriver.

Materials
2.4m length of 70 x 18mm softwood, four 70mm T-hinges with small screws.

Sundries
Four 60mm woodscrews, four ¼in. UNC x 20tpi bolts, M6 washers, 30mm panel pins, PVA wood glue, sandpaper, washing up sponge, gloss paint or varnish.

ALL PICTURES: MARK PARRISH

STEP-BY-STEP

Step 1

Use the dimensions on the printable plan at www.skyatnightmagazine.com/bonuscontent to mark out the timber to size. Your timber merchant may be able cut the softwood to length for you. All you then need to do is cut the 45° angles on each support section.

Step 2

Cut the sections to shape. Power tools can help here, but a handsaw or tenon saw works fine. It helps to hold the wood in a vice or clamp it to the bench. You may also wish to clamp some scrap wood to the bench to protect its surface.

Step 3

Glue the main sections together to form a two-layered cross. Use PVA wood glue for a strong fix. Reinforce the joints with panel pins to hold them together while the glue sets. Drill and countersink a 5mm hole 80mm from the end of each arm.

Step 4

Each hinge support needs a 3mm pilot hole for the screw. Ascertain each hole's position by testing with a hinge before drilling. The hinge should lie flat against the support and top of the cross. Fix each support from below with a screw (but no glue).

Step 5

Drill the outer hinge screwhole to 6.5mm for the camera screw. Each hinge needs to be bent to 90°. Bend 35mm from the end by clamping between the bench and some scrap wood. Make sure you bend it the way shown in the image above.

Step 6

After applying a nice varnish or paint finish, use small screws with pilot holes to attach the hinges. Test fit a camera to make sure it sits nicely. Adjust the bend of the hinge or introduce a bit of sponge padding to achieve a good fit.

▲ **If you're clever with your connections, one intervalometer can control all four cameras**

it will cover approximately 45x60° of sky. Full frame cameras are more expensive but give coverage closer to 60x90° for the same lens, so four could just manage a full 360° view. Don't be put off if you don't have four cameras; even two will double your chances of capturing that elusive image.

There are many considerations when determining the best direction in which to point your cameras, but find out the shower's radiant (the point from which the meteors are due to emanate above the horizon at midnight – for example, 40˚) and set the altitude accordingly. We suggest one camera pointing towards the radiant, with any additional cameras increasing your chances of a capture elsewhere. If you wish to avoid sky gaps between cameras you could experiment by turning the supports, which is why we decided not to glue them.

An intervalometer (remote timing/shutter control device) is also valuable, as this will enable you to set each camera to take regular exposures through the night. Connecting it all requires some crafty cabling. Start with a female to female audio jack that fits your intervalometer, and connect it to one end. Attach a 3.5mm splitter cable to the other end of the audio jack and then a splitter plug to each 'head' of the splitter cable. This gives you four sockets through which you connect four cameras to a single intervalometer.

All cameras have a standard threaded insert for attaching to a tripod (¼in.x20 threads per inch) and bolts of this size can be bought online. We used a rubber washer below the cameras and a few M6 metal washers in between each bolt and hinge to allow it to be tightened properly. If the cameras vibrate a bit when the mount is knocked you can wedge some foam (cut up a clean, dry washing up sponge) between the camera body and wooden support, which dampens any movement.

MORE ONLINE
Print a cutting template for this project

Build a back garden telescope pier

Get a permanent base for your telescope for less than £100

By Robert Lucas

Building a permanent post, or pier, for your telescope to sit on is the next step up from using a tripod. If you're observing the heavens through the eyepiece, it means you can be ready to begin in minutes, and it's ideal if you're an astrophotographer too. It'll be a more rigid platform for your kit that can't easily be knocked out of position. Plus, you only need to polar align your telescope once. You can buy telescope piers, but they're surprisingly expensive. Here, we'll show you how to build one for a fraction of the cost – all the materials for it come to less than £100.

The first thing to do is to choose a site for your pier. It should have a clear view of the north celestial pole so that you can polar align your scope, and should be relatively clear of obstacles and bright lights blocking your view. If you use a desktop computer for autoguiding or imaging, you might want to consider siting the pier close to a door, since the various USB and connecting cables are typically only about 5m long.

▲ The finished pier with mount and telescope attached

ALL PICTURES: ROBERT LUCAS

You can get most materials to build this pier from your local DIY store, apart from the underground drainage pipe used for the main column, the metal plate that the mount is attached to and some small metal spacer blocks. The pipe can be bought from a builders' merchants, while the metal plate, which is a piece of off-cut

STEP-BY-STEP

Step 1

Dig a hole to embed the bottom of your pier column. Remove any flagstones or other surface finishes first. The hole should be about 60cm deep; an irregular shape is fine. Put the earth you dig out in a wheelbarrow or on a large tarpaulin so it's easy to transport.

Step 2

Position a steel lintel in the centre of your hole and hammer it into the ground so that about 30cm is buried. It shouldn't budge if you try and move it. The steel lintel surrounded by the concrete mix and plastic pipe will give a strong base for your pier.

Step 3

Mix the concrete a batch at a time to suit the volume of your mixing container. Put the pipe onto the steel lintel, then fill the hole and the pipe with your concrete mix, keeping the pipe straight. Stir the concrete with a stick to check there are no air pockets.

TOOLS AND MATERIALS

Aggregate
For the concrete; nine bags of stone and sand mix.

Bolts
Four 12mm-diameter, 150mm-long.

Cement
For the concrete, three bags.

Hand tools
A shovel for mixing concrete and spanners for tightening bolts.

MDF sheet
12mm-thick sheet and L-shaped brackets to fix it to the pier column.

Nuts
Eight, to match the bolts.

Plastic dustbin
For the cover. Get one with clamps that secure the lid.

Steel lintel
Runs down the centre of the column to add strength; should be at least 1.2m long.

Strong plastic box
For mixing the concrete.

1.25cm-thick mild steel, can be sourced from your local engineering company. Get the spacer blocks here too; they support the collar of our mount (an HEQ5) making it even more steady. The base of your mount may be different, so check and measure your requirements first. You can also buy mounting plates tailor-made for your mount; some astronomical suppliers call them pucks.

The drainage pipe is filled with concrete to make it solid; mix three parts aggregate (stone and sand) to one part cement to make this. Both can be bought from any DIY shop and can be mixed a few bags at a time in a heavy-duty plastic storage box.

Solid state

You'll need four long bolts and eight nuts to secure the mounting plate to the top of the pier. We used 1.2cm-diameter bolts for the HEQ5 mount, but check the diameter of the holes the bolts will go through on your mount before you buy them. You'll also need to have six holes drilled in the plate. One is in the middle for attaching it to the mount; four go near the edge for the bolts that join the plate to the pillar. Finally, one should be on the north side of the plate to take a bolt for the mount's azimuth adjustment to work against.

Give the plate a couple of coats of metal paint to protect it from rust, then attach the bolts to the plate before filling the pipe with concrete. When the concrete reaches the top, sink the bolts into the wet concrete head-first and put two pieces of 20mm-thick wood between the pipe and the plate to support it. This will ensure that the bolts are set into the correct position, and as soon as the concrete is set you can remove the wood. The gap is important for getting the plate dead level, and for getting a bolt upwards through the middle hole to secure the mount.

▲ This image of M31 was taken with a scope mounted on the pier. It is six 10-minute exposures, stacked and dark-frame subtracted

To protect the mount head, you can fix a circular MDF table under the metal plate with L-shaped brackets, varnish it and seal the gap where it meets the pier, then cover this with a dustbin to create a watertight cover. The table was cut to the exact size of the top of the dustbin, which has two metal fasteners that hold it securely on the table. With the telescope and counterweights removed, the dustbin can be easily slipped over the mount. A coat of paint can brighten up the cover.

While this may not be the most beautiful observatory, it is entirely weatherproof and will reduce your setup time to just a few minutes so you can grab a quick opportunity to do some observing. It's also rock solid, enabling you to take stunning astro images completely untroubled by unwanted movements and vibrations.

Step 4

Screw the four bolts onto the plate and sink them into the wet concrete. Place some off-cuts of wood between the plate and the top of the column to keep it steady while the concrete dries. The plate needs a central hole for the screw that will fix the mount head to it.

Step 5

Leave the concrete for a week to set, then make the mounting plate level by adjusting the nuts on the bolts. Bolt your mount onto the plate ready for alignment. Note the three steel blocks that support the collar of the mount against the plate.

Step 6

Cut a circular table to fit the dustbin cover and secure this to the pipe with L-shaped brackets. Use sealant on the thin gap where it meets the pier. Fit the dustbin over the mount to protect it when not in use. A dustbin with metal fasteners will grip the table tightly.

▲ The finished mount – this design can be modified for any 8-inch or larger Newtonian telescope

Make a Dobsonian mount Part 1

Turn a sheet of plywood into the building blocks of a great mount

By Steve Richards

The Dobsonian telescope is simplicity itself: a Newtonian reflector mounted on a basic altaz mount. Many thousands of astronomers have constructed their own Dobsonians, but the satisfaction of building your own mount is immense – and that's what we're going to cover in this two-part project.

The dimensions of our design are based on a 10-inch Newtonian reflector, but you can work out what size components you need for any Newtonian with an aperture of 8 inches or more with the 'Calculations' spreadsheet in the bonus content section on www.skyatnightmagazine.com.

The mount is made from 18mm plywood, which has great strength and warp resistance. We chose to use cheaper Far Eastern plywood and give it a painted finish. Alternatively, you could opt for a natural wood finish if you use the more expensive birch plywood; this wood has a nicer grain, with fewer knots and blemishes, which gives a better result if you're varnishing. Apart from a plunge router, you only need standard tools and sundries. A full list, including all the bolts and screws needed for part 2, is on the website. To begin, enter the nine dimensions required in the yellow boxes of our Calculations spreadsheet found online. This generates the sizes for the wooden parts you need in the blue boxes. Transfer these figures to a diagram similar to the 'Cutting Template' on the website (allowing an extra margin for the altitude bearing wheels – see Step 3) and ask your timber merchant to cut the sheet for you.

Cutting circles

You should end up with six pieces: two equal squares for the base board and rocker box base; one short rectangle for the rocker box front; one long rectangle (we'll use this to make the box's sides); and two larger squares for the altitude-bearing wheels. Note that the 'Tube to Altitude Bearing Ratio' in the Calculations spreadsheet defines how large the altitude-bearing wheels will be.

TOOLS AND MATERIALS

Power tools
A plunge router for cutting the circular components of the mount; hand drill with 1.5mm and 2mm bits to make pilot holes.

Tape measure and pencil
Accurate measurements are essential for making sure that the mount assembles to a tight tolerance.

Telescope
This project assumes that you own or are going to acquire a Newtonian reflector tube with an 8-inch or greater aperture, as well as suitable tube rings and a pair of dovetail bars.

Wood
External-quality 18mm plywood is ideal for this project as it is strong and warp-resistant; make the router jig out of 3mm MDF.

ALL PICTURES: STEVE RICHARDS

Anywhere between 1.5x and 1.8x is fine; larger wheels result in smoother operation.

The figures produced in the red boxes in the Calculations spreadsheet are to help you make a circle-cutting jig (guiding template) for use with the plunge router. This jig is vital to turning the square altitude-bearing wheel 'blanks' into circles. First, cut a piece of 3mm MDF board to the dimensions given in Step 2, then mark and drill 2mm holes in the jig at positions 'a' to 'e', as per the numbers in the red boxes. Note that these positions are measured from the inner edge of the router bit. Replace the router's foot with this jig, then push a 2mm round nail through position 'a'.

Place one blank on the table, mark its centre by drawing a line diagonally from opposing corners to form a centre cross. Drill a small pilot hole. Place the router and jig on the board, then tap the nail into the pilot hole. Start the router and plunge it down by just 3mm; lock it and slowly rotate it around the nail in a complete circle. Plunge it down a further 3mm and cut a deeper circle. Continue until you have cut through the full thickness of the board. Repeat for the second blank.

You now have two circles. Follow one of the lines passing through the centre and mark the points ¼ and ¾ along it and drill pilot holes. Cut two holes in each wheel, with the pilot holes at the centre and the nail in the jig at position 'c'. Keep the two best cut-out discs for use as 'retainers' later on.

Altitude-bearing wheels complete, we need to make the sides of the rocker box. Mark the centre of the side panel sheet (the long rectangle), drill a pilot hole, then move the nail in the router jig to position 'b' and cut out another circle. This time the circle will be incomplete, leaving you with two rocker box sides with one scalloped edge. Mark the centre of each side and use the router to cut out further circles using position 'e'. Finally, cut a rectangular piece of ply 50mm deep by the width of the rocker box base for use as a brace. In part 2, we'll put the pieces together and finish off the mount.

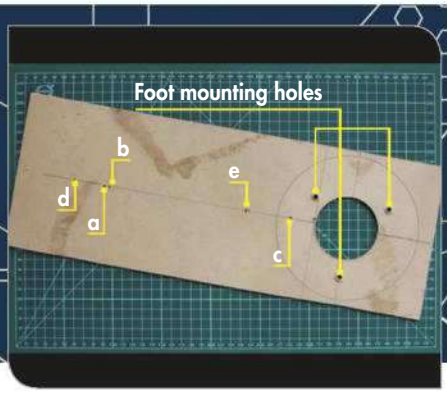
MORE ONLINE
Find the Calculations spreadsheet, component list and more

TURN THE PAGE FOR PART 2 ▶

STEP-BY-STEP

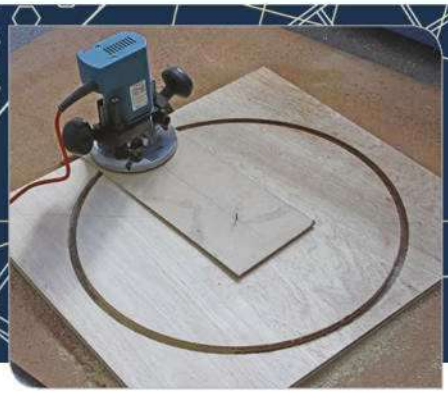
Step 1

Determine the telescope's balance position with your heaviest eyepiece installed and decide what clearance you want at the base of the scope. Use the Calculations spreadsheet to draw up a template for your timber merchant and get the parts cut out.



Step 2

Remove the plunge router's foot and use it as a template to cut the circle-cutting jig: its length should be 450mm, its width the same as your router. Mark the jig using the figures in the red boxes on the Calculations spreadsheet. Drill 2mm holes in these positions.

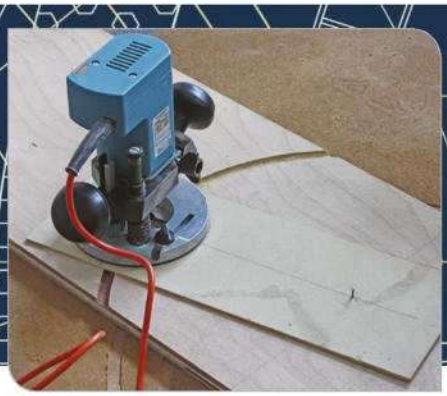


Step 3

Mark the centre of each square altitude-bearing wheel blank. Drill a small pilot hole at the centre. Attach the router by aligning a 2mm nail through the jig into the centre pilot hole. Carefully rotate the router around the nail to cut a circle. Repeat for the second blank.

Step 4

Pick one of the two altitude-bearing wheels cut out by the router. Choose one of your diagonal pencil lines and mark points ¼ and ¾ along. Drill pilot holes for the cut-outs then re-position the nail in the jig and rout out the two holes. Repeat for the other wheel.



Step 5

Select the side panel sheet and carefully mark the centre by drawing lines from opposing corners. Attach the router by aligning a 2mm nail through the jig into a pilot hole at the centre and rout two 'half moons'.

Step 6

Mark the centre of the two side panels you produced in Step 5 with lines from opposing corners again to form a cross at the centre. Attach the router by aligning a 2mm nail through the jig into a pilot hole at the centre and route a circle.

Make a Dobsonian mount Part 2

Assemble the mount so it's capable of supporting a telescope

By Steve Richards

▲ Nearly there: rocker box is assembled; all that's left is to add the base and bearing wheels

In Part 1, we showed you how to cut out all the wooden parts to make a Dobsonian mount. Now we'll walk you through assembly and finishing the mount ready for use. We'll be referring to the resources in the bonus content on our website throughout, so print these out before you begin.

Start by marking the centre of the rocker box base, then draw a line from one side to the other through this central point. Do the same for your base board.

Take the base board and – using the line you just drew as the 'horizontal' to rest against – use a protractor and ruler to mark off the various points indicated on Diagram 1 on the website. Drill the holes at the sizes specified on Diagram 1, and then a 12mm hole in the centre of the rocker box base, plus a 10mm hole in the centre of a vinyl LP you can bear to live without.

We'll assume that you have gathered all of the fixings, bearings and other parts listed in our online 'Components' list. Lightly coat the outside of one of the T nuts with epoxy resin and pull it into the top of the base board using a 10mm bolt and washers until it is firmly seated. Drill out the thread of the second T nut using a 10mm drill bit, and install it in the top of the rocker box base in the same manner – use a 10mm bolt, washers and nut.

Take one of the rocker box side panels and mark the centre point on its bottom inside edge; repeat for the other side panel.

Place the two side panels on top of the rocker box base so that the points you just marked match up with the line you drew across the base. Now position the front of the rocker box so that it touches the two sides. Mark its outside edge on the top of the rocker base. Now mark the height of the front piece on the edges of the two side panels; trim these 'horns' so the side panels sit flush against the front panel.

Glue and screw

Next, refer to Diagram 2 and drill out the nine 4.5mm holes in the rocker base as shown; countersink the holes on the reverse. Fix the rocker base, front and side panels together using PVA glue and 15 x No 8 1.5-inch screws (nine in the base, three in each side; these also need 4.5mm drilled holes).

Once the glue is dry, draw a pencil line perpendicular to the existing line (which you drew in Part 1) through the centre of each altitude wheel. Centre the dovetail bar of your telescope on this line both vertically and horizontally, then mark and drill the two holes for attaching the tube rings.

Sand all the components and round the corners of the two bases. Apply two coats of external-quality undercoat and topcoat paint to all surfaces, rubbing down between coats. Then reduce the height of the screw base and centre tube sections of the adjustable feet to 25mm and attach them to the underside of the baseboard with epoxy resin and No 6 ¾-inch screws.

TOOLS AND MATERIALS

Fixings and ancillary components
A complete list of all the fixings required to complete the assembly can be found at www.skyatnightmagazine.com/bonuscontent

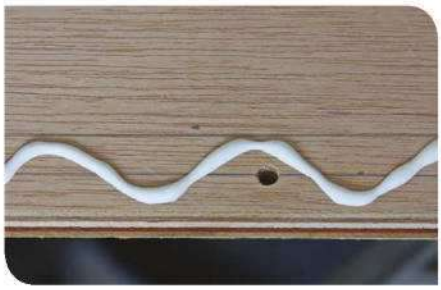
Tools
A standard crosshead screwdriver; Allen keys and spanners are required for some of the retaining bolts.

Paint or varnish
To give the mount protection from night-time moisture to prolong its life. Make sure the product you use is intended for outdoor use.

Tape measure, protractor and pencil
For accurately marking out the positions of the various components.

Adhesives
Both PVA wood glue and epoxy resin are needed.

ALL PICTURES: STEVE RICHARDS



▲ **Using both PVA wood glue and screws to secure the rocker base gives a sturdy end result**

To make the azimuth bearings, cut the PTFE sheet into three 25mm square pads (unless you are using 'Slide Glides'); secure these in the 1.5mm pilot holes in the rocker box base (see Diagram 1) using No 6 ¾-inch screws.

For the altitude bearings, cut four rectangular pieces of PTFE 25mm long by the width of the rocker box sides, then drill and countersink them. Attach them to the top of the rocker box sides spaced as close as possible to 70° apart.

Assembly time

Assemble the rocker box on top of the baseboard, sandwiching the LP – which will act as a ridged bearing surface – as shown in Diagram 3. Make sure that you leave a 0.5mm gap under the bolt head before tightening the locknut underneath the baseboard.

Cut the edging strip to the correct width with scissors and attach it with impact adhesive to the perimeter of the altitude wheels, securing the ends with No 6 ¾-inch screws and cup washers. Bolt the two circular retainers (the wooden discs you kept over from Part 1) to the centre top of the rocker box sides and apply felt to the inside surface.

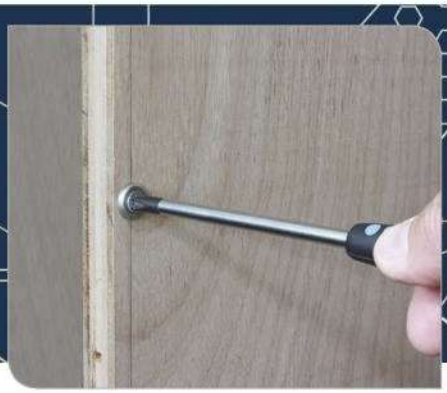
To finish, attach the altitude wheels to the tube rings, sandwiching the dovetail bars, using oversize washers on the outside. Gently lower the altitude wheels into the bearing 'cups' to complete the assembly. As a final option, you can use the swing of the telescope to determine the position for the attachment of a bracing bar.

MORE ONLINE
Drilling diagrams and a parts list

STEP-BY-STEP

Step 1

Mark the centre of the rocker box base and drill a 12mm hole. Mark and drill the holes in the baseboard in accordance with Diagram 1. Drill the threads out of one T nut to form a smooth bearing and insert both T nuts.



Step 2

Place the sides and front on the rocker box base and mark their positions carefully. Drill and countersink 4.5mm holes through the rocker box base for attaching the sides and front. Glue and screw the rocker box together using 1.5-inch wood screws.

Step 3

When the glue has dried, sand all the surfaces, including the altitude wheels and the retainer discs. Round off all four corners of the rocker box base and baseboard with a small radius. Apply two coats of external-quality undercoat, followed by two topcoats.

Step 4

Cut down the height of the adjustable feet and install them on the underside of the base board. Attach the three azimuth-bearing pads to the baseboard at 120° positions. Attach the altitude-bearing pads to the top of the sides, followed by the side retainers and felt.

Step 5

Place the vinyl LP centrally on the azimuth-bearing pads then place the rocker box centrally over the baseboard. Insert a 10mm bolt through the rocker box's smooth T nut, the vinyl LP and into the T nut on the base board; tighten with a nyloc nut underneath.

Step 6

Attach edging strips to the altitude-bearing wheels and then attach the tube rings to the telescope. Attach the altitude-bearing wheels to the tube rings with oversize washers, sandwiching the dovetail bars. Finally, lower your scope gently onto the rocker box's 'cups'.

IMAGING

Find out how to build astrophoto accessories for all levels of expertise, from a smartphone holder to an automated camera that's ideal for 360° meteor imaging campaigns. Our projects will ensure every image you take is a great one

BACKGROUND IMAGE: ISTOCK, DAVID UTTING, MARK PARRISH, STEVE RICHARDS

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Using wing nuts to assemble your adaptor lets you swap eyepieces without tools

Make your own smartphone adaptor

By David Utting

It's amazing what you can do with a few bits of old metal

Gone are the days when the camera on your mobile phone was only capable of producing fuzzy, low-res images. Some are now so good they rival dedicated point and shoots, and can be used with a telescope to image brighter targets such as the Sun, Moon and planets. Their large displays make group observing much more fun, while internet connectivity and apps make it easy to edit and share your shots quickly.

Using a smartphone to image the night sky relies on 'afocal' imaging, meaning the camera is placed in front of the eyepiece instead of replacing it. But lining up a phone lens with a telescope eyepiece for a stable shot can be tricky. You can buy brackets, but here we'll show you how to make a sturdy, adjustable adaptor that's compatible with a range of eyepieces. It's comprised of three parts: a phone holder, a telescope clasp and a bracket to link the two.

Start with templates

You need to make two wooden templates, one for your smartphone and another that matches the diameter of your eyepiece's body. Jot down the dimensions of your smartphone, then saw a block of wood to those measurements to make a template. Do the same for the eyepiece; alternatively, you could use an old eyepiece barrel instead.

We used aluminium from the back of an old computer case for our phone holder, but you could use a different metal so long as it's sturdy but can still be cut to shape. Cut your metal 2cm larger than the surface of your phone and bend the surplus over

> "You can buy brackets, but here we'll show you how to make a sturdy, adjustable adaptor that's compatible with a range of eyepieces"

the edges of your wooden phone template – this creates the metal tabs that will hold the phone securely in place. Use a hacksaw to remove a small section on the back so that the camera lens isn't obscured – see how we've removed the upper right corner of ours in the image on the left.

Trim the tabs so the phone's buttons and headphone socket are accessible. To attach the holder to the bracket with a bolt, first drill a small 2mm hole close to the holder's centre. Then recess this to prevent the bolt head from scratching your phone: make a 45° countersunk hole in the wood template and line this up with the hole in the holder, then use the centre bit from a lathe and a hammer to widen and recess the hole. Fix a wing nut and bolt through the hole – this will link the holder to the bracket.

Clasp and bracket

For the bracket, take a strip of aluminium and drill a series of holes along its length. Cut or file out the metal between the holes to create two slots – see the image for Step 3 (right). The slots allow you to adjust how the camera lens lines up with different eyepieces. Bend the whole bracket so it's at a right angle. The bracket needs to be long enough to allow the scope clasp to attach below the eyepiece.

▲ Large screens are a boon when taking afocal images of bright targets, such as the Moon

ALL PICTURES: DAVID UTTING

STEP-BY-STEP

Step 1

Use a saw to cut out the templates to the dimensions of your phone and eyepiece. You'll need these to shape the finished adapter and bracket. You could also use an old eyepiece body in place of the wooden eyepiece template, if you have one.

Step 2

Cut the metal to the size of your phone template, leaving some excess to create tabs. Cut out a section so the camera lens isn't obscured. Drill a 2mm hole for the bracket attachment bolt, then widen and recess it with a lathe centre and hammer.

Step 3

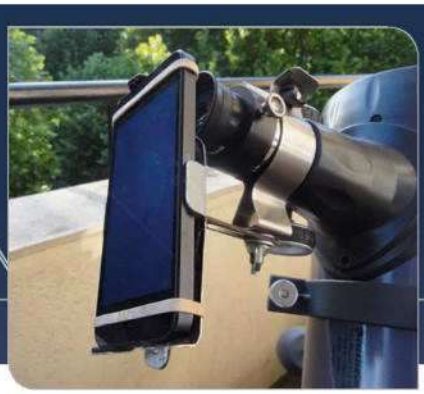
Cut a strip of aluminium for the bracket using a hacksaw. Drill a series of holes, then saw or file out the metal between them so you end up with two slots. These are the adjustment slots to slide the connectors along. Bend the bracket by 90° to finish it.

Step 4

Take another strip of metal and mould it around the eyepiece template using pliers so it looks like the above. This forms the clasp that attaches to the telescope. Line it with felt to help protect the focuser drawtube from being scratched.

Step 5

Connect the phone holder and clasp to the bracket using wing nuts. You can now loosen the screws and slide the adaptor closer or farther away to match the eyepiece on your telescope. Using wing nuts allows you do this without tools.



Step 6

Place the phone in your adaptor and fasten it with strong elastic bands to prevent it from slipping. If your phone's headphones have a remote volume adjustment facility, you can use it as a remote shutter release to avoid camera shake.

TOOLS AND MATERIALS

Materials
Wood for the templates, a thin sheet of metal for the mount, felt for lining.

Sundries
Two threaded bolts, two wing nuts and four washers for the adaptor, plus a longer bolt and a captive nut to secure the clasp around the focuser drawtube or eyepiece body.

Tools
Hammer, drill, ruler, hacksaw, file, metal cutters, pliers, glue and lathe centre.

Finish
Felt glued along the insides of the adapter and holder to prevent scratching.

For the telescope clasp, cut another aluminium strip long enough to fit around your wooden eyepiece template one and a half times – roughly 20 x 2cm. Drill a hole at each end and one in the middle. Fix a wing nut and bolt through the middle hole so you can attach it to the bracket. Bend the strip around your template with pliers, leaving a triangular space for the bolt head – see the image for Step 4. The ends of the strip should be parallel, allowing you to fit a clamping bolt between them and secure the clasp to the focuser drawtube.

Assemble the adaptor by connecting the holder to the bracket and the bracket to the clasp – using wing nuts enables you to put the adapter together (and adjust it when you're observing) without tools. File off any sharp edges and line the inside of both the clasp and holder with felt to prevent scratches.

To change eyepieces with the adaptor in place, loosen the wing nut for the telescope clasp and swivel the mount 180° – we'd recommend securing the phone in the holder with elastic bands before doing this so your phone doesn't end up on the floor.

Make a pinhole camera for solargraphy

By Vince Sellars

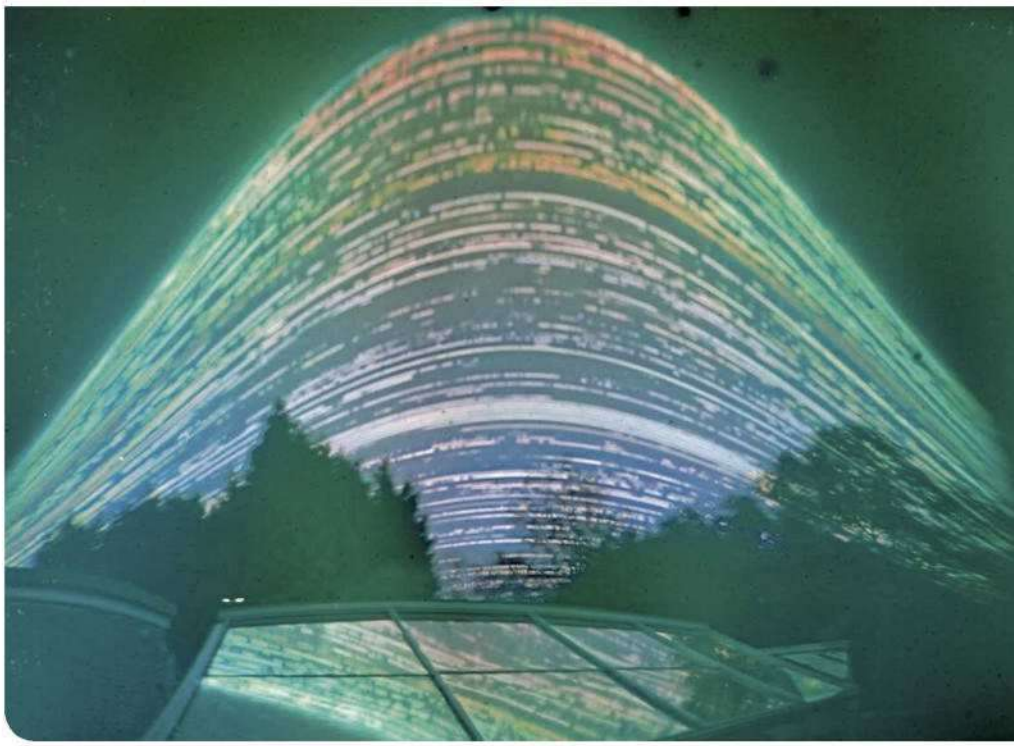
The low-effort way to trace the path of the Sun across the sky

Solargraphy is an easy branch of astrophotograpy to get involved in, and one that delivers impressive results for little effort – so long as you are prepared to wait. A solargraph is a long-exposure star-trail type of image, but rather than tracking the night sky rotating around the north celestial pole, it shows the path of our Sun across the sky. And we really do mean long exposure. The solargraph capture you see on the right had an exposure time of six months.

Capturing this type of photo doesn't require any expensive or specialist astro imaging gear – only a pinhole camera, a device that you can easily make at home using readily available materials. Here we're going to show you how to do just that. After reading this article, you'll be able to use it to produce your own record of the Sun's progress.

This form of solar photography is completely safe. A pinhole camera does not have a lens in it that can refract, focus and intensify sunlight – this means it can be safely left pointing directly at the Sun for the duration of the exposure. It is also not necessary for anyone to look at the Sun when using this technique; all that is required is a knowledge of which general direction in the sky the Sun is going to be when choosing a suitable site for the camera.

You may be concerned about privacy, seeing as each exposure can last for



▲ A six-month, solstice to solstice solargraph exposed in the UK during 2011

ALL PICTURES: VINCE SELLARS

STEP-BY-STEP

Step 1

Choose a weatherproof container unless you are going to place the camera indoors. Drill or cut a 6mm hole in the container. For solargraphy, it is best for the hole to be closer to the top; ours was cut 4cm from the top on this container.

Step 2

Use a pin to make a hole in a small square of aluminium foil. This is where the light from the view will project through onto the photo paper inside. Mask off the pinhole with black tape, then tape it over the outside of the container so it lines up with the drilled hole.

Step 3

Paint the inside of the container with matte black paint or line it with black card to minimise any unwanted internal reflections. Make sure the pinhole is not covered. Affix a small patch of black tape over the pinhole to act as a shutter.

▲ This five-day exposure was captured with a pinhole camera made from a peppermint tin

months at a time. This is not an issue either, as people do not show on any of these long exposure images unless they remain still for the duration of the capture – which, given the time periods involved, would be quite an achievement.

You can use any sort of photographic paper in your pinhole camera, and this is readily available from any retailer than sells photographic supplies. Photographic papers, being of low sensitivity, are ideal for long exposures and usually perform very well for solargraphs. No chemical processing is necessary after the exposure is completed; the paper negative is simply scanned into a computer using a flat-bed scanner. Once you have done this, you can use processing software to invert, flip or rotate the scanned image, or enhance the solargraph if desired.

Choosing a location

Your completed pinhole camera can be sited almost anywhere, but you should make sure you get permission from the site owner and be sure not to trespass on anyone's property when choosing a location. You should also consider which direction you aim the camera. In the northern hemisphere, it is best to avoid pointing the pinhole north, as it will see very little direct sunlight. The exception is if you are planning on capturing a 'reflected' solargraph, for example from window glass or a mirror-windowed building. In the southern hemisphere it is best to avoid pointing the camera south for the same reason. Locations that are well-lit by sunlight, whether that be direct or reflected, will give the best results in terms of foreground detail.

Exposures don't have to last for months, however – they can be as brief as a few hours for a short solargraphy trail. That said, the results are usually more impressive when they are exposed for longer periods. A three-month exposure, say from an equinox to a solstice or vice versa, is a good duration. This will expose a lot of trails onto the solargraph. However, a relatively short duration solargraph of only a few days can also produce excellent results. When you scan solargraphs exposed on black and white photographic paper it can produce a nice colour tint.

TOOLS AND MATERIALS

Tools
Scissors, ruler, emery paper, straight pin, drill.

Materials
Any suitable container (tall, cylindrical ones are good for solargraphy), aluminium foil, photographic paper, black tape, matt black paint.

Hardware
Computer with a flat-bed scanner.

The main image in this article is an example of a six-month solargraph exposed in the UK from solstice to solstice during 2011, using a pinhole camera made from a tall cylindrical canister as shown in the step-by-step guide below. So, why not have some fun making your very own solargraphy pinhole camera? It could provide you with a unique photographic memory of the Sun's apparent path through the sky at home, at one of your favourite places or maybe of a special holiday location.

Step 4

Under dimmed lighting, cut the photo paper to fit the container. Use it to line the inside of the container, with the emulsion side facing inwards and centred facing the pinhole. Once inserted, seal the top so the container is lightproof.

Step 5

Choose a location with a good view of the Sun's path across the sky. Make sure the container is located somewhere where it will be safe and you have permission to set it up. Remove the tape from the pinhole to begin the exposure.

Step 6

After a suitable length of time, cover the pinhole and retrieve the camera. In dimmed light, remove the photo paper and scan it on a flat-bed scanner to produce the solargraph. Use photo-editing software to enhance the image if desired.

BIG BUILD

With your imaging centre set up, you'll be ready for a night of hassle-free astrophotography

Make a laptop IMAGING CENTRE

By Mark Parrish

Build a stand and shade for your laptop to make outdoor digital imaging easier

Visit any star party these days and you will not fail to notice the proliferation of glowing laptops connected by trailing 'umbilical cords' of cables and leads to mounts and telescopes. Many amateur astronomers are drawn towards the world of digital imaging and, whether it is driving a camera or webcam, controlling mounts or processing images, a laptop is an essential tool for any astrophotographer.

"Laptops are not really designed for outdoor use. Our imaging centre provides a safe place where they won't be inadvertently knocked, dropped or trodden on"

Using a laptop under the night sky is not without its problems, though. At night, the screen's glow is distracting for other observers, and in bright sunlight solar imagers find it hard to see the display screen. Laptops are not really designed for outdoor use, either. They need protection from dew and a safe place to sit where they won't be inadvertently knocked, dropped or trodden on. Our

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS

Paint
You'll need brushes or small rollers to paint the various parts. Water-based preservative wood finishes work well on outer surfaces. For the best results, apply a coat of matte black paint inside the shield too.

Timber
Use softwood sections for the legs and the battens, thin plywood for the work surface, the side panels and the roof, and 12mm hardwood dowel for the stand assembly.

Tools
You'll need a hand saw, a drill with bits to suit the dowels, a hammer, panel pins and glue.

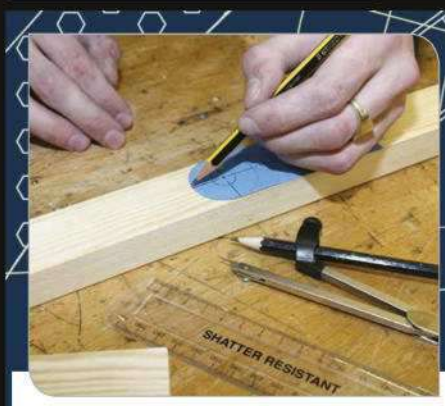
laptop imaging centre solves all these problems and also provides a convenient place to put small accessories during your imaging sessions. We have designed it to be sturdy, compact and easy to fold up for storage and transport. It's suitable for a typical 15-inch laptop and can be built from easy-to-obtain materials with basic tools. We've provided plans with detailed dimensions at www.skyatnightmagazine.com/bonuscontent. If you're feeling more ambitious, you may want to customise your imaging centre, and we offer some suggestions for this later on.

Shaded work surface

The laptop imaging centre has two main parts: the stand and the shaded work surface. If you already have a suitable garden table, you may decide to omit the stand. However, building a stand does enable you to use the imaging centre in remote spots with minimal bother. For storage or transport, the shade's side panels fold flat and the work surface folds flat against the legs. In our design, the detachable roof panel clips to the work surface, providing a space in between to store the folded side panels, so you can carry the whole thing with one hand.

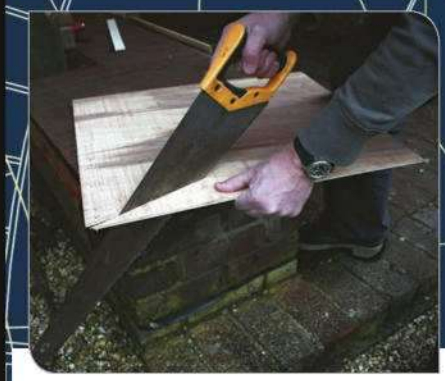
We chose 18 x 18mm and 34 x 18mm softwood for the stand as it is easy to buy and straightforward to cut and shape with hand tools. If your timber supplier doesn't stock the exact cross-sections specified on the plan, choose the closest size and ▸

STEP-BY-STEP



Step 1
Carefully mark out all the pieces according to the plans on our website. It is a good idea to put similar parts side by side and mark them at the same time to ensure they are identical. Make a card template to draw the rounded ends on the legs.

Step 2
Use a hand saw to cut the softwood sections. A bench vice is useful to hold the wood steady. Cutting the dowel is done in a similar way, but a finer saw like a hacksaw works best. Wrap masking tape round the dowel before cutting to prevent splitting.



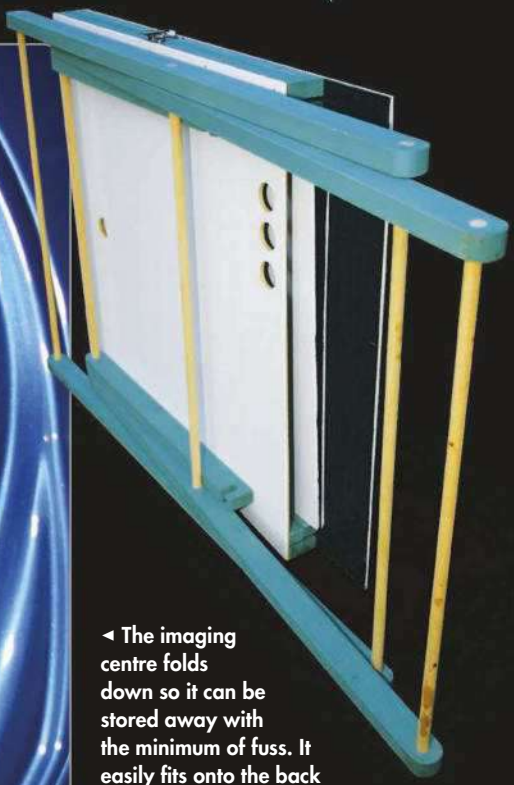
Step 3
A hand saw works well for cutting the panels too. If you have access to a jigsaw you can speed things up, but take care to keep edges straight and don't cut into your best table! A timber merchant might do most of the work for you if you are lucky.

Step 4
Drill holes in the legs and rails to suit the dowel you are using. We used 12mm dowel with a 12.5mm (0.5-inch) drill. This means the pivoting joints move smoothly and the fixed joints are easy to stick with wood glue. Saw the corners and sand smooth.

Step 5
Once all the woodwork has been done and the individual parts are nice and smooth you can paint them. We used a gloss-finish preservative wood stain for our stand and gloss paint for the outside of the shade. Inside it is matte black.

Step 6
The dowels are glued into the leg holes at either end. The inner legs turn freely on the middle dowel. The folding hinges of the shade are made with duct tape. Glue and pin the battens to the roof panel and work surface to form the slots for the side panels.

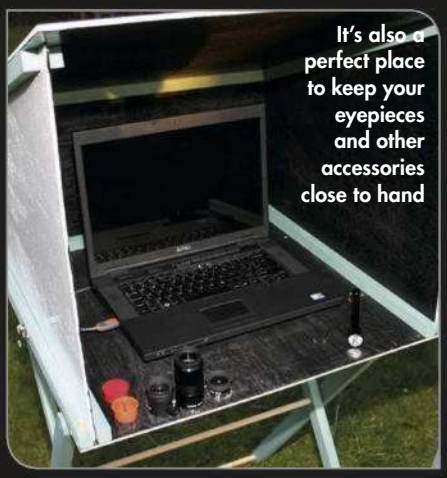
BIG BUILD



◂ The imaging centre folds down so it can be stored away with the minimum of fuss. It easily fits onto the back seat of a small car

▸ make adjustments to the dimensions accordingly. Our work surface and shade are made from 6mm plywood. Any thin board will work for the shade – even cardboard – but because it will often be used in moist air, a good coat of gloss paint is recommended if you want it to last.

Sticking strips of strong waterproof duct or gaffer tape on the inner and outer faces of the side and back panels is a simple way to make the hinges, but make sure you leave a slight gap between the panels so that they can fold flat.



It's also a perfect place to keep your eyepieces and other accessories close to hand

ALL PICTURES: MARK PARRISH

Finishing touches

We found that a dark or matte black shade interior enhanced the view of the screen, especially for daytime use. A preservative finish or paint is desirable for the timber stand – it ensures a longer life but also looks nicer. Colour is a matter of personal taste, although a light colour is easier to see in the dark and may prevent your setup being knocked at star parties. The surface of the unit could be decorated with graphics or you could even attach laminated charts and maps to help you locate your targets.

Before assembly, drill some generous holes near the rear of the work surface for routing power and camera cables. Assemble the finished parts with waterproof wood glue and panel pins. Note that the stand's three long horizontal dowels are only glued into the outer legs, so the inner legs can move.

Although the unit is compact, there is room for a few small accessories and we drilled holes near the front for 1.25-inch eyepieces. You could easily add some Velcro strips for attaching equipment such as a Go-To mount's handset or a motorised focus controller. For that personal touch, you may consider night vision-friendly red lighting or external shelves. Whatever features you decide to include, we're sure you'll find your laptop imaging centre invaluable when working outdoors.

MORE ONLINE
Find extra photos and printable plans

Laptop imaging centre
SET-UP

Once it's built, follow this five step sequence to pop up your imaging centre

▲ Start with your table folded flat, in a clear area on even ground

▲ Next, raise and lock the legs into position

▲ Unclip and remove the roof and place it to one side

▲ Unfold the side panels and fit them into their corresponding slots

◄ Finally, fit the roof on top and you're ready to go for a night of imaging

A Bahtinov mask is easy to make and will help you take pin-sharp astro images with your DSLR camera

Make a Bahtinov mask

By Steve Richards

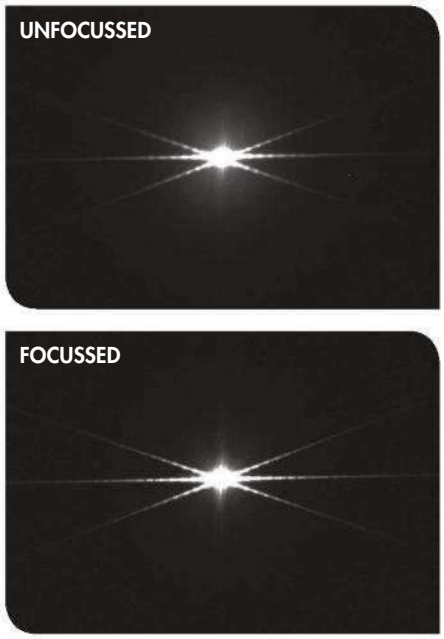
Ensure the shots of the stars you take with a DSLR are in perfect focus with the help of this simple device

There are many important factors that go into a good astro image, but focus is by far the most crucial. No matter how colourful, well framed or well exposed your photos may be, if they're out of focus they'll be spoilt beyond repair.

Now, it would seem fair to assume that focusing a DSLR camera would be easy – simply look through the viewfinder and adjust the focus; after all, that's how a single-lens reflex camera is designed to work. But if you try this method you'll be rather disappointed, because a DSLR camera's viewfinder is intended for daylight use; it just can't cope with small, dim, night-sky objects. Things are getting a little easier, though, as many of the newest DSLR cameras have a live view function that lets you see the view through the telescope directly on the camera's built-in LCD screen.

If you don't have a live view function, one method of finding focus is to use special image capture and star analysis software to download the image from the camera and examine it on a laptop. The problem is it isn't always convenient to have a laptop outside with you. One solution is an excellent focus tool that you can make called a Bahtinov mask. The mask is a clever focusing device invented by the respected Russian astrophotographer Pavel Bahtinov. If focus is an issue in your astrophotography then a Bahtinov mask is for you.

You simply place the mask over the front of your telescope, which you then point at a suitably bright star. It works by adding a specific pattern of diffraction spikes to your test star image, rather like those produced by the spider vane of a Newtonian reflector. Unlike the simple spikes produced by a spider vane, however, the diffraction spikes from the Bahtinov mask produce a bright, elongated cross with a third, horizontal line running through it. The aim is to adjust the focus with the scope's focuser until the horizontal diffraction spike is centred in the cross formed by the other two diffraction spikes. The 'Before' and 'After' images above show the difference between an in-focus view and an out-of-focus view.



▲ When a star is in focus the horizontal diffraction spike will be centred between the cross made by the diagonal spikes

To get an accurate focus with your DSLR attached to the telescope, you'll need to

TOOLS AND MATERIALS

Adhesive
For an instant bond, apply impact adhesive to surfaces.

Cardboard
Make the mask out of 300gsm white cardboard.

Insulation tape
Use electrician's tape to protect the sleeve.

Tools
Use a craft knife to cut out the slots and tabs, with a steel ruler to guide you.

Transparent Fablon
Apply transparent adhesive-backed plastic to protect the mask.

ALL PICTURES: STEVE RICHARDS

"Making your Bahtinov mask is a true *Blue Peter*-style project involving paper, cardboard and sticky-back transparent plastic"

take a continuous series of images that are of sufficient exposure length to show the star brightly in your camera's LCD preview screen after it has been captured. Alternatively, if your camera has live view, use that to examine the star's diffraction pattern. To make the procedure as quick as possible you should use a higher ISO number for focusing than you would use for the actual imaging. This makes your DSLR more sensitive to light and so will allow you to take a star image suitable for focus purposes in a shorter period of time. Don't forget to set the ISO number back to your preferred setting and remove the mask when you begin your actual imaging run, however.

Sticky-back plastic

Making your Bahtinov mask is a true *Blue Peter*-style project involving paper, cardboard and sticky-back, transparent plastic. First of all you need to enter your telescope's parameters into the online template generator at astrojargon.net/MaskGenerator.aspx. This is because, importantly, each mask has to be tailored for your particular telescope. This isn't a 'one size fits all' solution, so you'll need to know the following dimensions for your telescope in millimetres: the clear, unobstructed aperture; the diameter of your scope's front end; and its focal length.

Once you have this information, visit the website mentioned above and simply fill in your data to download a customised template. This produces a Scalable Vector Graphics (SVG) file, which can be opened by many graphics programs including the popular Gimp software (download it for free at www.gimp.org), and printed out to make your Bahtinov mask.

STEP-BY-STEP

Step 1

Print off your template and add stiffness and moisture proofing by sticking transparent Fablon material to the printed sheet. Cut out all the slots with a craft knife and steel ruler, being careful not to damage either yourself or the mask.

Step 2

Cut out the circular shape of the mask, leaving a 1-inch margin from which you can cut out triangular tabs, with the base of each at the printed edge of the mask. These tabs will be used to attach the mask to the cardboard sleeve.

Step 3

Make the inner sleeve that slides over the front of your telescope by cutting a 1-inch wide cardboard strip that's slightly longer than the circumference of the scope. Wrap it around the telescope, overlapping and gluing the ends to form a collar.

Step 4

Leaving the sleeve in position, place the mask over the front of the telescope and bend the triangular tabs around the rim of the mask over the cardboard collar. Glue the tabs to the collar, taking care not to get any glue on the telescope.

Step 5

Cut a similar strip of cardboard to the one in step 3, but about 10mm longer. Carefully glue this around the first collar that now has the mask attached to it with the triangular tabs. The idea is to trap the mask's tabs between the two layers of cardboard.

Step 6

Reinforce the new structure by wrapping electrician's insulating tape around the outside of the collar. Don't stretch the tape too much as it could contract and distort the collar, making it more difficult to slide it on and off your telescope.

Make a MiniSolarCam

By Mark Parrish

This portable, pocket-sized solar webcam is great for imaging the surface of the Sun

ALL PICTURES: MARK PARRISH

The MiniSolarCam can be piggybacked on a scope, as it is here, or mounted on a tripod

This MiniSolarCam is a simple telescope equipped with a solar filter that can be used to observe and record solar events and sunspot activity using a webcam. It's a fun little project for long summer days or when you're waiting for the skies to clear.

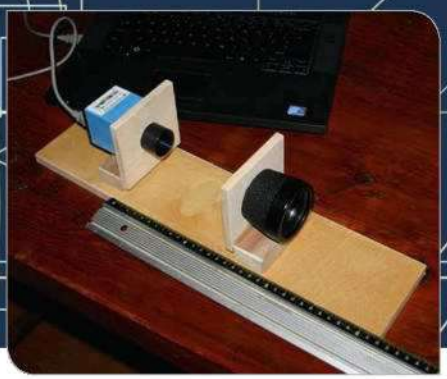
It must always be stressed that you should take great care when observing the Sun. Never look directly at it, and never point this or any other telescope towards the Sun without first fitting and securing a proper solar filter over the objective lens. Ensure other telescopes or finders on the same mount are similarly filtered or have their objectives securely covered, and never leave a setup unattended.

Although this diminutive instrument uses the objective lens from a discarded pair of binoculars and a handful of plumbing parts, it is surprisingly effective and is a useful addition to any solar observing setup. We've used ours to provide a live feed of eclipse and transit events, and it can also be used for basic imaging – perhaps for logging sunspot development. Because it's so small, it's also the perfect travel companion to help you keep track of solar activity wherever you go.

WARNING
Do not look directly at the Sun with the naked eye or any unfiltered optical instruments

Like most of our DIY build projects, making the MiniSolarCam requires only basic tools and minimal practical skills. You can find old binoculars at car boot

STEP-BY-STEP



Step 1

Once you've dismantled the binoculars, make a temporary frame to hold the objective lens and webcam in line. Slide them back and forth until you can focus on a distant object. The distance between them determines the length of the telescope tube.

Step 2

Cut a short length of pipe and split it so that it fits around the objective assembly. Cut similar sections and glue them inside to form a collar. Don't glue the objective in place until you have checked everything, and painted or lined the inside black in Step 5.

Step 3

A standard 1.25-inch nosepiece should fit snugly inside the 34mm tube if you make two slits at the end. When you have test-fitted this nosepiece holder, you can glue the objective-holding collar onto the other end of the push-fit connector.

sales and charity shops – or perhaps in your attic or shed. A pair with a 50mm objective lens is ideal, but we made do with a 40mm one.

Once you've dismantled the binoculars, you need to make a simple test frame to hold the objective and the webcam in line. We used offcuts of plywood to build our rig. Connect the camera and slide the parts back and forth until you can focus on a distant object. A lamppost at night is an ideal choice. Remember, you should not point the objective assembly towards the Sun itself until the project is complete and it is properly filtered.

Allow for focus

When focused, the distance between the objective and nosepiece determines the length of your telescope tube. By adding a push-fit connector in the middle of the tube, small adjustments to the instrument's length can be made to achieve accurate focus. We cut the nosepiece holder tube so that it could slide in and out by about 10mm either side of the measured overall length, giving us a good range for focusing.

It's also a good idea to take the time to check the fit of the parts regularly during construction to ensure that they all function correctly.

Our mount consists of two pipe brackets that grip the connector. We screwed these to a plywood offcut, which is easy to mount on a camera tripod or piggyback onto a larger telescope. A little improvisation might be required for your own particular setup.

Solar film is quite expensive, but after making our MiniSolarCam, plus a filter for a 4-inch refractor, we still had some left over. You might be able to share a sheet with someone, or scrounge an offcut to keep your costs down. Baader Planetarium's solar film comes with instructions for making a filter, but the main thing is to make sure that it fits snugly onto the objective. Electrical tape can be used to ensure it can't pop off during use. Try to keep the film flat, but don't worry about slight wrinkles.

We've used the MiniSolarCam with a dedicated astronomical camera and a standard webcam (with a 1.25-inch nosepiece adaptor) with good results. High-resolution solar imaging requires quality optics, driven mounts, stacking software and a fair degree of knowledge and experience. But for the short-duration, low-magnification imaging required to keep a record of sunspots, this simple setup produces great results. At night, you can also remove the filter and try some lunar imaging with this miniscope.

"Although this diminutive instrument uses the lens from a discarded pair of binoculars and a handful of plumbing parts, it is surprisingly effective"

TOOLS AND MATERIALS

Optics
An objective lens assembly from a pair of medium-sized binoculars, and a webcam with 1.25-inch nosepiece or adaptor.

Plumbing parts
A short offcut of 34mm waste pipe, a 34mm push-fit straight connector, an offcut of pipe to suit the objective (50mm approx) and some mounting clips.

Solar film
This critical component reduces the intensity of sunlight. Baader Planetarium and Thousand Oaks Optical produce solar films that can be bought in sheets.

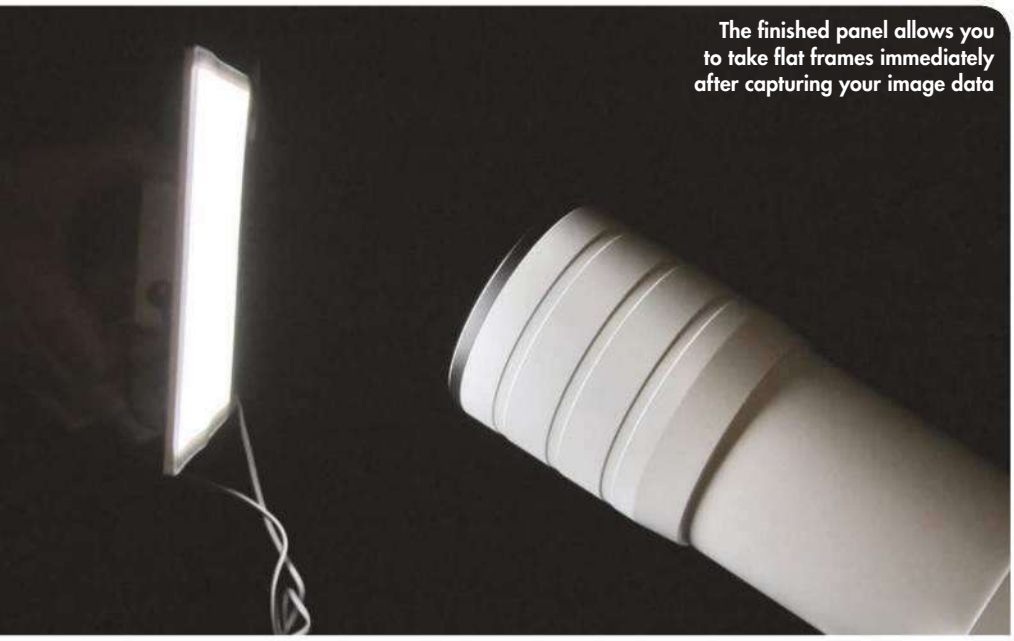
Sundries
You'll need a sheet of craft foam or card and some duct tape for the filter, and some black paper or spray paint to line the telescope tube.

Tools
Coping saw or hacksaw, craft knife, scissors, screwdriver and a hot-melt glue gun.

Step 4
Make sure the spacing between the objective and nosepiece matches your measurement in Step 1, then trim the nosepiece tube to the right length and assemble the parts. Try the webcam to check that you can focus on a distant object – but not the Sun at this stage.

Step 5
Once all the main elements have been made, you should blacken the inside of the tube. Spray paint or rolled-up black paper works well. Pipe brackets are an effective way of mounting the tube onto a wooden base that can be fitted to a tripod or telescope.

Step 6
Wrap a strip of foam or card around the objective and tape or glue it together. Cut out a pair of card or foam rings with a gap that matches your aperture. Cut a disc of solar film and carefully place it across the aperture, then glue the filter together.



The finished panel allows you to take flat frames immediately after capturing your image data

Make and use a flats panel

By Steve Richards

This easy way of taking flat frames will help your image processing

To get the most from deep-sky image data, it's necessary to calibrate your subframes before stacking and processing them into a final image. There are three types of calibration that can be applied to your images: bias frames, to remove signal noise caused by the action of downloading your data; dark frames, to remove thermal noise produced when your sensor warms up; and flat frames, to remove the effects of vignetting and dust motes. Whereas bias and dark frames can be easily captured at any time, flat frames require careful planning and execution, which means they're often overlooked in the excitement of capturing new images.

A flat frame is a special image taken in such a manner that only a facsimile of the plain light cone passing through the telescope to the camera sensor is captured. The typical way of doing this is to cover the front of the telescope with a white cloth and take a series of images with the telescope pointing at the daytime sky. It's vital, however, that the orientation of the camera and focus position are maintained between the capture of the celestial images and the flats, and therein lies the problem – you must not disturb the imaging train until the flats have been captured!

There is a fairly simple solution, though: you can use an electroluminescent panel to provide an evenly distributed light source and capture your flats during an imaging session without disturbing the camera or its focus position.

Electroluminescent panels comprise three components – the panel itself (a thin laminated plastic sheet), a 12V inverter that produces an alternating current in the 120V range and a 12V power source. The panels are available in a range of sizes from A6 to A1; choose one that's slightly larger than the aperture of your telescope to ensure complete coverage.

Securing your panel

Because electroluminescent panels tend to be a little flimsy, it should be affixed to a backing board. The ideal material for this is the 4mm-thick corrugated plastic sheet often used for signboards: this material is light, smoothly finished, moisture-proof and surprisingly strong. By applying masking tape to the rectangular shape of the electroluminescent panel (allowing 40mm over the panel length to comfortably support their notoriously fragile electrical connections) you can cut a very neat backing board to size. The panel can be attached to this backing board using double-sided adhesive tape.

As the electrical connections to these panels are so delicate, it's worth making a loop in the cable near to where it enters the

"You can use an electroluminescent panel to provide an evenly distributed light source and capture your flats without disturbing the camera or its focus position"

▲ The North America Nebula; deep-sky shots can be transformed by flat-field calibration

ALL PICTURES: STEVE RICHARDS

TOOLS AND MATERIALS

Components
An electroluminescent panel slightly larger than the diameter of your telescope, an inverter module, 12V power supply and power lead.

Materials
Heavy duty 4mm-thick corrugated plastic sheet.

Sundries
Double-sided adhesive tape, electrician's tape, masking tape, methylated spirit.

Tools
A cutting board, scissors, craft knife, metal straight edge, pencil.

panel and securing this to the backing with electrician's tape to act as an emergency strain relief. The inverter module can be fixed to the rear of the backing with double-sided tape to act as a handle and ensure that no physical tension is applied to the interconnecting cable.

To capture worthwhile flat frames it's important to get the exposure right. Typically, this means achieving between 30 and 50 per cent of the full well capacity (saturation level) of the sensor elements. With a DSLR, this is easily achieved by setting it to aperture priority (Av) mode and letting it automatically choose the exposure time. Astronomical CCD users can use capture software to determine the ADU (Analogue Digital Unit) value, which is a measure of the individual pixel values in a CCD image and should be in the range of 20,000 to 30,000 units.

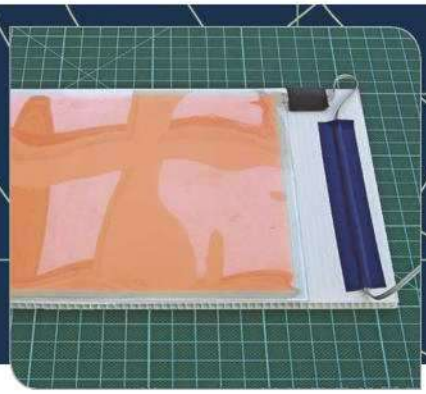
You'll need to capture 20 or so subframes, which then need to be stacked to produce a master flat frame using a median combine method. These should then be divided into each image frame to apply the calibration. Many stacking programs, including the freeware DeepSkyStacker, will do this for you. You'll be astonished at the improvement in your images.

STEP-BY-STEP

Step 1
Measure the panel. Mark out the size on the plastic sheet in masking tape, adding 40mm to the length. Draw a precise outline (plus 40mm to the length) on the tape in pencil. This extra length will be used to support the panel's electrical connections.

Step 2
Cut out the rectangle from the plastic sheet. For the best results hold the blade vertically and make several shallow cuts rather than a single deep one. Also note that it is much easier to cut down the web of the sheet than across it.

Step 3
Add a new strip of masking tape to mark the true length of electroluminescent panel, then remove all other tape. Clean the sheet and rear of the panel with methylated spirit, then apply double-sided tape around the perimeter and on the masking tape.



Step 4
Apply a strip of double-sided tape to the panel's electrical connection. Now fix the panel to the tape applied in Step 3, ensuring that the pink side is uppermost. Form a small loop in the wiring and secure it to the board with electrician's tape.

Step 5
Turn the panel over and clean the rear of the sheet and the base of the inverter with methylated spirit. Once it's evaporated, apply double-sided tape to the base of the inverter module and fix it firmly to the back of the plastic sheet.

Step 6
Connect the inverter to the panel and power supply to turn it on. Hold the panel over the front of the telescope, ensuring that it's central over the aperture and capture 20 exposures in readiness for producing a master flat to apply to your images.

Make an all-sky **camera enclosure**

▲ Your biggest concern during construction is keeping the dome clean and scratch free

Capture timelapses without worrying about wet weather and dew

By Steve Richards

Several planetary imaging cameras are now packaged with wide-field lenses as well as standard ones. Providing you wrap the lens in a dew heater and can be sure of a rain-free night, they allow you to capture timelapses of the stars wheeling across the night sky. But if there's any risk of inclement weather then the camera and lens are at risk of being damaged. The solution is to protect the camera with a suitable waterproof enclosure, and that's what we're showing you how to make in this project.

The versatile all-sky enclosure discussed here was built around a ZWO ASI 120MM planetary imaging camera, but the enclosure will accommodate a range of other models – all you need to do is construct a suitable mount for attaching the camera to the base. The design is also compatible with fish-eye lenses, should you want an even wider field of view. The domed section must be heated to keep dew at bay on both the lens and the inner and outer surfaces of the dome so this design includes a variable power heater that provides up to 6W of heat output.

Start by printing out the dome template from the bonus content section at www.skyatnightmagazine.com. Cut out and fix the template to the top of the enclosure – in this case an IP56-rated junction box – using masking tape. Drill a 2mm hole through the centre mark as a guide for cutting the 2-inch camera aperture.

The plastic dome must be handled very carefully to avoid scratches; use a wad of clingfilm to protect it. Place the dome over the template, holding it in place with masking tape. Drill the six 4mm mounting holes through the dome's flange and the lid of the junction box. Placing a 4mm bolt through each hole helps ensure alignment.

Remove the dome. In the lid, drill the 4mm holes needed for the heater element, then use a hole cutter to create the 2-inch hole in the centre. Cut a 110mm-diameter piece of flock material and affix it centrally on the lid to keep unwanted reflections to a minimum. Cut out the centre hole and the heater holes in the flock using a craft knife.

▲ The finished enclosure can be mounted on a permanent post like this, or a regular tripod

Putting it together

Push a 130cm length of nichrome wire through the 1.6mm heat-shrink tubing leaving 10mm exposed at each end and heat-shrink the tubing. Make a circular heating element that just clips over the heater stand-offs by passing the wire through

TOOLS AND MATERIALS

Components
Clear 100mm acrylic dome with 20mm flange, IP56-rated PVC junction box (190x140x70mm), 32 SWG nichrome resistance wire (130cm length), two-way terminal block, 12V LED dimmer controller, two-core speaker cable, heat shrink tubing.

Tools
Hand drill, 2mm and 4mm bits, 2-inch hole-cutter, Allen keys, crosshead screwdriver, 7mm metric spanner, small square file.

Sundries
Sandpaper, black flocking material, silicone sealant, marker pen, masking tape, tape measure, bolts, washers and nuts.

Optional
Rubber feet, small dovetail bar, 22mm overflow pipe, pipe clips, pipe T connector and 1/4-20 bolt.

ALL PICTURES: STEVE RICHARDS

▲ A single frame from a timelapse video recorded through the acrylic dome

three pieces of 5mm heat-shrink four times and then shrink the outer tubing.

Attach the six M4x16mm bolts to the lid with a nut either side of the lid to form stand-offs for the heater element. Clip the heating element over the stand-offs with the wire ends exiting through the seventh hole in the lid. Connect the heater element to one end of the speaker cable using a terminal block.

Carefully apply a bead of clear silicon to the underneath of the dome flange, place it on the lid and attach it firmly using M4x20mm bolts, washers and nuts.

Drill and file a hole in the box base such that the USB cable just fits though. Decide on your box mounting method – rubber feet for tabletop use, a dovetail bar with a 1/4-20 mounting hole for tripod use, or permanent installation using waste pipe and a 0.25-inch bolt through a pipe T connector – and attach the necessary components to the base. Construct a suitable mount for your particular camera and lens combination and install the camera in the centre of the base. If you are using a ZWO ASI camera, use the hole template included in the bonus content and attach the camera with four spacers, nuts and washers.

Attach the lid to the box base with the supplied screws, connect the speaker cable to the LED light dimmer and connect the dimmer to a 12V power source. You're now ready to capture some stunning wide-field vistas of the night sky.

MORE ONLINE

Go to www.skyatnightmagazine.com/bonuscontent for cutting templates

STEP-BY-STEP

Step 1

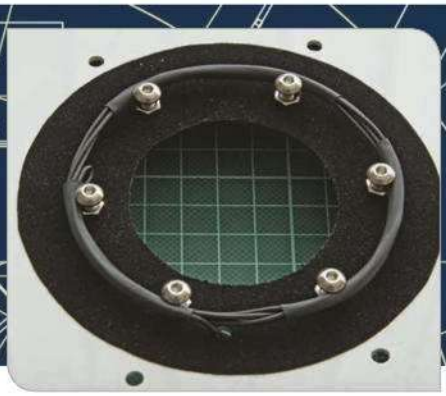
Attach the dome template from the bonus content online to the lid of the junction box. Drill a 2mm pilot hole through the centre mark. Place the dome accurately on top of the dome template and drill six 4mm holes through the dome and box lid.

Step 2

Remove the dome, then drill the seven 4mm holes for the heater element stand-off bolts and the wire exit point. Using the centre 2mm pilot hole drilled in Step 1 as a guide, use a 2-inch hole-cutter to cut out the hole for the lens.

Step 3

Cut a 130cm length of nichrome wire and thread it through the 1.6mm heat-shrink tube and shrink it using a hair dryer or heat gun. Cut three 6cm lengths of 5mm-diameter heat-shrink tubing and thread the wire through them four times to form a circle.



Step 4

Attach the M4x16mm heater stand-off bolts to the lid with nuts, washers and locknuts. Heat-shrink the heater ring and clip it over the stand-offs. Push the wire ends through the seventh hole and connect them to the terminal block using the two-core speaker cable.

Step 5

Run a bead of silicone around the underneath of the dome flange – do this as close to the middle of the flange as possible to ensure an accurate spread. Place the dome on the lid and affix it with the six M4x20mm bolts, washers and nuts.

Step 6

Cut a hole in the base and push the USB and heater cables though. Drill suitable holes in the base and attach the rubber feet and dovetail bar, if required. Make a mount for your camera and lens and place them at the centre of the base to complete the project.

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